IMP. INST. ENTOM.
— LIBRARY —
No. 7899

ICAR. 17. VIII.
800.

Vol. VIII

1938

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the Authority
of
The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 24s.

Price per part
Rs. 3 or 5s. 3d.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI
1939

Price annas 6 or 7d.

List of Agents in India from whom Government of India Publications are available.

(*a*) Provincial Government Book Depots.

Madras :—Superintendent, Government Press, Mount Road, Madras.
Bombay :—Superintendent, Government Printing and Stationery, Queen's Road, Bombay.
Sind :—Manager, Sind Government Book Depot and Record Office, Karachi (Sadar).
United Provinces :—Superintendent, Printing and Stationery, U. P., Allahabad.
Punjab :—Superintendent, Government Printing, Punjab, Lahore.
Central Provinces :—Superintendent, Government Printing, Central Provinces, Nagpur.
Assam :—Superintendent, Assam Secretariat Press, Shillong.
Bihar :—Superintendent, Government Printing, P. O. Gulzarbagh, Patna.
North-West Frontier Province :—Manager, Government Printing and Stationery, Peshawar.
Orissa :—Press Officer, Secretariat, Cuttack.

(*b*) Private Book-sellers.

Advani & Co., The Mall, Cawnpore.
Aero Stores, Karachi.*
Banthiya & Co., Ltd., Station Road, Ajmer.
Bengal Flying Club, Dum Dum Cantt.*
Bhatia Book Depot, Saddar Bazar, Ranikhet.
Bhawnani & Sons, New Delhi.
Bombay Book Depot, Charni Road, Girgaon, Bombay.
Book Company, Calcutta.
Booklover's Resort, Taikad, Trivandrum, South India.
Burma Book Club, Ltd., Rangoon.
Butterworth & Co. (India), Ltd., Calcutta.
Cambridge Book Co., Booksellers, New Dak Bungalow Road, Patna.
Careers, Mohini Road, Lahore.
Chatterjee & Co., 3, Bacharam Chatterjee Lane, Calcutta.
Chukervertty, Chatterjee & Co., Ltd., 13, College Square, Calcutta.
City Book Club, 98, Phayre Street, Rangoon.
Das Gupta & Co., 54/3, College Street, Calcutta.
Dastane Brothers, Home Service, 456, Raviwar Peth, Poona 2.
Delhi and U. P. Flying Club, Ltd., Delhi.*
Deshmukh Book Depot, Station Road, Sholapur.
Educational Book Depot, Mahal Road, Nagpur.
English Book Depot, Ferozepore.
English Book Depot, Taj Road, Agra.
English Bookstall, Karachi.
English Book Store, Abbottabad, N.-W. F. P.
Faqir Chand Marwah, Peshawar Cantonment.
Gautama Brothers & Co., Ltd., Meston Road, Cawnpore.
Higginbothams, Madras.
Hindu Library, 137-F, Balaram De Street, Calcutta.
H. L. College of Commerce, Co-operative Stores, Ltd., Ahmedabad.
House of Knowledge, Booksellers and Publishers, Palliagraharam, P. O. Tanjore.
Hyderabad Book Depot, Chaderghat, Hyderabad (Deccan).
Ideal Book Depot, Rajpur Road, Dehra Dun.
Imperial Book Depot and Press, near Jama Masjid (Machhliwalan), Delhi.
Imperial Publishing Coy., Lahore.
Indian Army Book Depot, Dayalbagh, Agra.
Indian Army Book Depot, Daryaganj, Delhi.
Indian Book Shop, Benares City.
Indian School Supply Depot, Central Avenue South, P. O. Dharamtala, Calcutta.
Insurance Publicity Co., Ltd., Lahore.
International Book Service, Poona 4.
Jaina & Bros., Mori Gate, Delhi and Connaught Place, New Delhi, Messrs. J. M.
Kamala Book Depot, 15, College Square, Calcutta.
Keale & Co., 65, Britto Road, Karachi Sadar.
Keshao Book Stall, Khadi Bazar, Belgaum.
Kitabistan, 17-A, City Road, Allahabad.
Krishnaswami & Co., Teppakulam, P. O., Trichinopoly Fort, Messrs. S.
Lahiri & Co., Ltd., Calcutta, Messrs. S. K.
Local Self-Govt. Institute, Bombay.
London Book Co. (India), Arbab Road, Peshawar, Murree, Nowshera, Rawalpindi
Mackwin & Co., Booksellers, Stationers and New Agents, Inverarity Road, off Esphenstone Street Karachi Sadar.
Malhotra & Co., Post Box No. 94, Lahore, Messrs. U. P.
Malik & Sons, Sialkot City.
Mathur & Co., Messrs. B. S., Chatur-Vilas, Paota. Civil Lines, Jodhpur (Rajputana).
Minerva Book Shop, Anarkali Street, Lahore.
Modern Book Depot, Bazar Road, Sialkot Cantonment.
Mohanlal Dossabhai Shah, Rajkot.
Mohendra Bros., Lashkar, Gwalior State, Messrs.
Nandkishore & Bros., Chowk, Benares City.
New Book Co., "Kitab Mahal", 192, Hornby Road, Bombay.
Newman & Co., Ltd., Calcutta, Messrs. W.
Oxford Book and Stationery Company, Delhi, Lahore. Simla, Meerut and Calcutta.
Parikh & Co., Baroda, Messrs. B.
Pioneer Book Supply Co., 20, Shib Narayan Das Lane, Calcutta and 219, Cloth Market, Delhi.
Popular Book Depot, Grant Road, Bombay.
Punjab Religious Book Society, Lahore.
Raghunath Prasad & Sons, Patna City.
Rama Krishna & Sons, Booksellers, Anarkali, Lahore.
Ram Krishna Bros., Opposite Bishrambag, Poona City.
Ram Narain Lal, Katra, Allahabad.
Ramesh Book Depot and Stationery Mart, Kashmere Gate, Delhi.
Ray & Sons, 43, K. & L. Edwardes Road, Rawalpindi, Murree and Peshawar, Messrs. J.
Roy Chowdhury & Co., 72, Harrison Road, Calcutta, Messrs. N. M.
Saraswati Book Depot, 15, Lady Hardinge Road, New Delhi.
Sarcar & Sons, 15, College Square, Calcutta, Messrs. M. C.
Sarkar & Co., Ltd., 18, Shama Charan De Street, and 6, Hastings Street, Calcutta, Messrs. P. C.
Sharada Mandir, Ltd., Nai Sarak, Delhi.
Standard Bookstall, Karachi.
Standard Bookstall, Quetta.
Standard Book Depot, Lahore, Delhi and Simla.
Standard Law Book Society, 79/1, Harrison Road, Calcutta.
Tara & Sons, Razmak (India), Messrs. B. S.
Taraporevala Sons & Co., Bombay, Messrs. D. B
Thacker & Co., Ltd., Bombay.
Thacker, Spink & Co., (1933), Ltd., Calcutta.
Tripathi & Co., Booksellers, Princes Street, Kalbadevi Road, Bombay, Messrs. N. M.
Uberoy, J. C., Journalist, Printer and Publisher, Jaycee House, Alexandra Road, Ambala.
Universal Book Depot, 58, Hazratganj, Lucknow.
University Book Agency, Kacheri Road, Lahore.
Upper India Publishing House, Ltd., Literature Palace Aminuddaula Park, Lucknow.
Varadachary & Co., Madras, Messrs. P.
Venkatasubban, A., Law Bookseller, Vellore.
Wheeler & Co., Allahabad, Calcutta and Bombay, Messrs. A. H.
Young Man & Co. (Regd.), Egerton Road, Delhi

---

*Agent for publications on Aviation only.

S = ref. read

CONTENTS OF VOL. VIII

Part I (February, 1938)

Original articles—

		PAGE
INHERITANCE OF EARLINESS IN UNITED PROVINCES RICES, II (WITH PLATE I AND ONE TEXT-FIGURE)	*R. L. Sethi, M.Sc. (Pb.), B.Sc. (Edin.-Agri.), I.A.S.; B. L. Sethi, M.Sc., Ph.D. (Wales) and T. R. Mehta, B.Sc., Assoc. I. A. R. I.*	1
COTTON BOTANY AND THE SPINNING VALUE AND HAIR PROPERTIES OF COTTON LINT	*J. B. Hutchinson and G. K. Govande*	21
ALTERNARIA BLIGHT OF CUMIN (WITH PLATES II-IV)	*B. N. Uppal; M. K. Patel and M. N. Kamat*	49
THE *TUR*-POD FLY, *AGROMYZA OBTUSA* MALL., A PEST OF *CAJANUS CAJAN* (WITH PLATE V)	*Taskhir Ahmad, Ph.D. (Cantab.)*	63 S
STUDIES IN THE PRESERVATION OF FRUIT JUICES, I. SOME OBSERVATIONS ON THE PREPARATION AND PRESERVATION OF CITRUS FRUIT SQUASHES (WITH PLATE VI)	*Lal Singh, B.Sc. (Hons.), M.Sc. (Calif.) and Girdhari Lal, Ph.D. (Lond.), D.I.C.*	77

Part II (April, 1938)

Original articles—

THE PRESENT STATE AND FUTURE DEVELOPMENT OF POTATO BREEDING	*R. N. Salaman; M.D., F.R.S.*	119
STUDIES IN PLANT BREEDING TECHNIQUE, III. CROP ANALYSIS AND VARIETAL IMPROVEMENT IN MALVI *JOWAR*	*J. B. Hutchinson; V. G. Panse; N. S. Apte and B. M. Pugh*	131
MILLING AND BAKING QUALITIES OF TWO NEW PUSA WHEATS	*B. P. Pal* . . .	153
MICRO-CLIMATOLOGY OF AN IRRIGATED COTTON FIELD IN SIND (WITH PLATE VII AND FOURTEEN TEXT-FIGURES)	*B. M. Dabral, M.Sc. and S. S. Chiney, B.Sc.*	161
SOME LEAF DISEASES OF *HEVEA BRASILIENSIS* NEW TO INDIA (WITH PLATE VIII)	*M. Mitra and P. R. Mehta*	185
NOTE ON *CEPHALOSPORIUM SACCHARI* BUTL. (CAUSAL ORGANISM OF SUGAR-WILT)	*L. S. Subramaniam and B. L. Chona*	189

		Page
Studies on *Platyedra gossypiella* Saunders (the Pink Boll-worm of Cotton) in the Punjab, Part IV. The Incidence of *Platyedra gossypiella* in relation to Climate (1926-1931) (with three text-figures)	*M. Haroon Khan, B.Sc. (Lond.), A.R.C.S.*	191

Entomological note—

A Note on *Stenobracon deesae* (Cam.), A New Parasite of the Root-borer of Sugarcane (with Plate IX)	*E. S. Narayanan, M.A.* .	215

Part III (June, 1938)

Original articles—

Studies in Indian Fibre Plants, No. 5. Further Studies on the Inheritance of certain Characters in *Hibiscus sabdariffa* L.	*R. B. Deshpande, M.Ag. (Bom.), Assoc. I.A.R.I.*	229
Studies in Vernalisation of Mustard (A Preliminary Report) (with Plate X)	*B. Sen and S. C. Chakravarti*	245
Preliminary Studies in the Respiration of Sugarcane *in situ* (with five text-figures)	*K. L. Khanna and P. C. Raheja*	253
Soil Uniformity Trials in the Punjab, I (with seven text-figures)	*P. E. Lander, M.A., D.Sc., F.I.C., I.A.S.; Ramji Narain, Ph.D., D.Sc. and Azmat Singh, L.Ag.*	271
Comparison of Methods for the Estimation of the Furfuraldehyde Yield of Soils and Composts	*C. N. Acharya, M.Sc., Ph.D., A.I.C.*	309
Pruning of Fruit Trees : The Effect of Dormant pruning on Cropping and Vegetative Vigour of *Phalsa* (*Grewia asiatica*) (with Plates XI-XIII and one text-figure)	*Lal Singh, B.Sc. (Hons.), M.Sc. (Calif.) and Sham Singh, B.Sc. (Agri.-Pb.), Ph.D. (Bristol), F.R.H.S.*	319
Studies on Groundnut Nodule Organism, I. Isolation of Strains and Study of Cultures (with one text-figure)	*T. Rajagopalan, B.A., M.Sc.*	331
Studies on Groundnut Nodule Organism, II. Life-cycle of the Organism (with Plates XIV and XV)	*T. Rajagopalan, B.A., M.Sc.*	349

		Page
Studies on Groundnut Nodule Organism, III. Physiology of the Organism: Fermentation Characteristics (with three text-figures)	*T. Rajagopalan, B.A., M.Sc.*	357
Studies on Groundnut Nodule Organism, IV. Physiology of the Organism—Intermediary Metabolism: Carbohydrates and Nitrogen (with six text-figures)	*T. Rajagopalan, B.A., M.Sc.*	379

Review—

Applied Mycology and Bacteriology 403

Part IV (August, 1938)

Original articles—

Studies in Indian Fibre Plants, No. 6. Phyllody and some other Abnormalities in the Flower of Sunn-hemp (with Plates XVI and XVII)	*R. D. Bose, B.Sc. and S. D. Misra, M.Sc.*	417
A Note on the Occurrence of Chlorophyll Deficiency in *Gossypium arboreum*	*J. B. Hutchinson and Bhola Nath*	425
A Note on Seed-setting and Seed-germination in certain Sugarcanes (with Plate XVIII)	*N. L. Dutt, M.Sc.; M. Krishnaswami, M.A. and K. S. Subba Rao, B.A.*	429
A Note on the Use of Sub-acetate of Lead in the Clarification of Sugarcane Juice for the Estimation of Reducing Sugars by the Potassium Ferricyanide Method	*K. L. Khanna and S. C. Sen*	441
Denitrification in the Presence of Sugars (with one text-figure)	*S. V. Desai, D.Sc., Ph.D., D.I.C. and Fazal-ud-Din, B.Sc.*	447
Studies on Quality in Rice, I. Effect of Milling on the Chemical Composition and Commercial Qualities of Raw and Parboiled Rices (with two text-figures)	*V. Subrahmanyan, D.Sc., F.I.C., F.N.I.; A. Sreenivasan, M.A., D.Sc., A.I.C. and H. P. Das Gupta, M.Sc.*	459
A Study of the Microbiological Conditions existing in Rice Soils	*Pran Kumar De and Nripendra Mohon Bose*	487
The Distribution, Status and Biology of Codling Moth (*Cydia pomonella* L.) in Baluchistan with Notes on some other Insects infesting Apples (with Plates XIX-XXIV and two text-figures)	*Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.), F.N.I.*	499

		PAGE
A NOTE ON SOFT ROT OF PEARS CAUSED BY A SPECIES OF *ASPERGILLUS* (WITH PLATE XXV)	*H. H. Prasad* . . .	549
OBSERVATIONS ON THE MILLING OF RICE IN THE UNITED PROVINCES (SUPPLEMENTARY NOTE)	*R. L. Sethi, M.Sc., B.Sc. (Edin.), I.A.S.; B. L. Sethi, M.Sc., Ph.D. (Wales); T. R. Mehta, B.Sc. and P. S. Gupta, M.Sc. (Luck.), M.Sc. (Lond.)*	553

Part V (October, 1938)

Original articles—

THE DESCRIPTION OF CROP-PLANT CHARACTERS AND THEIR RANGES OF VARIATION—	*J. B. Hutchinson; K. Ramiah and the Members of two Special Sub-Committees*	567
I. THE VARIABILITY OF INDIAN COTTONS (WITH PLATES XXVI-XXXVII)		
II. VARIABILITY IN RICE (WITH PLATES XXXVIII-LIII)		
HABIT OF THE COTTON PLANT AND ITS INFLUENCE ON OPTIMUM DATE OF APPLICATION OF NITROGENOUS FERTILIZER (WITH THREE TEXT-FIGURES)	*Frank Crowther, D.Sc., A.R.C.S., D.I.C.*	617
A NOTE ON BORDER EFFECTS IN MANURIAL EXPERIMENTS ON COTTON AT SAKRAND DURING 1935-36 (WITH ONE TEXT-FIGURE)	*B. M. Dabral, M.Sc. and S. S. Chiney, B.Sc.*	629
SOILS OF THE DECCAN CANALS, I. GENETIC SOIL SURVEY AND SOIL CLASSIFICATION : NIRA RIGHT BANK AND PRAVARA CANALS (WITH PLATES LIV-LVI AND EIGHT TEXT-FIGURES)	*J. K. Basu, M.Sc. (Cal.), Ph.D. (Lond.) and S. S. Sirur, B.Ag. (Bom.)*	637
A STUDY OF FACTORS INFLUENCING THE EXTRACTION OF JUICE FROM SUGARCANE	*Ramji Narain, Ph.D., D.Sc. and Azmat Singh, L.Ag.*	699
A HYPODERMIC SYRINGE FOR USE WITH HAND REFRACTOMETER IN SUGARCANE (WITH PLATE LVII AND ONE TEXT-FIGURE)	*K. L. Khanna* . . .	719

		Page
Studies on the Root-rot Disease of Cotton in the Punjab, V. Confirmation of the Identity of *Rhizoctonia bataticola* (with three text-figures)	*Jai Chand Luthra, M.Sc., D.I.C. (Lond.), I.A.S. and R. Sahai Vasudeva, B.Sc., Ph.D. (Lond.), D.I.C. (Lond.)*	727
Biology and General Morphology of *Leucopis griseola* Fall. (Chamaemyidae, Diptera), an Important Predator of *Aphis gossypii*, and some other Aphid Pests of Crops (with Plate LVIII)	*Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.), F.N.I. and H. L. Bhatia, M.Sc.*	735

Reviews—

Report of the Fourth International Grassland Congress	....	741
The Frameworking of Fruit Trees	....	745

Part VI (December 1938)

Original articles—

Studies in Plant Breeding Technique, IV. The Inheritance of Agricultural Characters in three Interstrain Crosses in Cotton	*J. B. Hutchinson; V. G. Panse and G. K. Govande*	757
Shortening the Rest Period of the Potato (*Solanum tuberosum* L.) (with Plate LIX and four text-figures)	*B. P. Pal and Pushkar Nath*	777
Agricultural Meteorology: Frequency of Days with Hail-storms in India (with fourteen text-figures)	*L. A. Ramdas, M.A., Ph.D.; V. Satakopan, M.A. and S. Gopal Rao, B.A.*	787
Studies on Quality in Rice, II. Chemical Composition of Rice Varieties	*V. Sadasivan, B.Sc. (Agri.) and A. Sreenivasan, M.A., D.Sc., A.I.C.*	807
Estimation of Manganese in Plants	*A. V. Varadaraja Iyengar, B.A., D.Sc., A.I.C., A.I.I.Sc.*	819
A Method of Dispersion of Soils for Mechanical Analysis	*Jogendra Nath Chakraborty*	829
The Ammoniacal, Nitrate and Total Nitrogen Contents of Rice Soils	*N. S. Bamji*	839

		PAGE
LIFE-HISTORY AND MODES OF PERPETUATION OF SMUT OF SUGARCANE (*USTILAGO SCITAMINEA* SYD.) (WITH PLATE LX)	*Jai Chand Luthra, M.Sc., D.I.C. (Lond.), I.A.S.; Abdus Sattar, B.Ag., Assoc. I.A.R.I., Ph.D., D.I.C. (Lond.) and Sardul Singh Sandhu, M.Sc. (Ag.)*	849
NEW ASILIDAE FROM INDIA, II (DIPTERA: ASILIDAE) (WITH FOUR TEXT-FIGURES)	*Stanley W. Bromley, Ph.D.*	863

Selected article—

THE DEVELOPMENT OF SOIL MECHANICS .	*F. L. D. Wooltorton, B.Sc., A.M.Inst.C.E.*	869

INDEX TO VOL. VIII

A

PAGE

Abdus Sattar (Luthra, J. C. and)—Life-history and modes of perpetuation of smut of sugarcane 849

Acharya, C. N.—"Comparison of Methods for the Estimation of the Furfuraldehyde Yield of Soils and Composts" 309

Agricultural characters, inheritance of, in three inter-strain crosses in cotton (Hutchinson, J. B. *et al.*) 757

Agricultural meteorology: frequency of days with hail-storms in India (Ramdas, L. A. *et al.*) 787

Agromyza obtusa, a pest of *Cajanus Cajan* (Ahmad, T.) . . . 63

Ahmad, Taskhir—"The *Tur*-pod Fly, *Agromyza obtusa* Mall., a Pest of *Cajanus Cajan*" 63

Alternaria blight of cumin (Uppal, B. N. *et al.*) 49

Andropogon Sorghum (Malvi *jowar*), crop analysis and varietal improvement in (Hutchinson, J. B. *et al.*) 131

Aphid pests of crops, biology and general morphology of *Leucopis griseola*, an important predator of (Pruthi, H. S. and Bhatia, H. L.) . . 735

Aphis gossypii, *Leucopis griseola*, an important predator of (Pruthi, H. S. and Bhatia, H. L.) 735

Apples, insects infesting (Pruthi, H. S.) 499

Apte, N. S. (Hutchinson, J. B. and)—Studies in plant-breeding technique 131

Asilidae from India (Bromley, Stanley W.) 863

Aspergillus, soft rot of pears caused by a species of (Prasad, H. H.) . 549

Azmat Singh (Lander, P. E. and)—Soil uniformity trials in the Punjab 271

——— (Ramji Narain and)—Factors influencing the extraction of juice from sugarcane 699

B

Baking qualities of two new Pusa wheats (Pal, B. P.). . . . 153

Baluchistan, distribution, status and biology of Codling moth in (Pruthi, H. S.) 499

Bamji, N. S.—"The Ammoniacal, Nitrate and Total Nitrogen Contents of Rice Soils" 839

PAGE

BASU, J. K. and SIRUR, S. S.—"Soils of the Deccan Canals, I. Genetic Soil Survey and Soil Classification : Nira Right Bank and Pravara Canals" 637

BHATIA, H. L. (PRUTHI, H. S. and)—Biology and general morphology of *Leucopis griseola* 735

BHOLA NATH (HUTCHINSON, J. B. and)—Chlorophyll deficiency in *Gossypium arboreum* 425

Biology of codling moth (PRUTHI, H. S.) 499

——— *Leucopis griseola* (PRUTHI, H. S. and BHATIA, H. L.) . . 735

Blight (*Alternaria*) of cumin (UPPAL, B. N. *et al.*) 49

Boll-worm (pink) of cotton in the Punjab, studies on (HAROON KHAN, M.) 191

Border effects in manurial experiments on cotton (DABRAL, B. M. and CHINEY, S. S.) 629

BOSE, N. M. (DE, P. K. and)– Microbiological conditions existing in rice soils 487

BOSE, R. D. and MISRA, S. D.– "Studies in Indian Fibre Plants, No. 6. Phyllody and some other Abnormalities in the Flower of Sunn-hemp" 417

Brassica juncea (see "mustard") 245

Breeding of plant, technique of (HUTCHINSON, J. B. *et al.*) . . . 757

BROMLEY, STANLEY W.– "New Asilidae from India, II (Diptera : Asilidae)" 863

C

Cacoecia sarcostega Meyr., notes on (PRUTHI, H. S.) 514

Cajanus Cajan, *Agromyza obtusa*, a pest of (AHMAD, T.) . . . 63

Cephalosporium sacchari, causal organism of sugarcane wilt (SUBRAMANIAM, L. S. and CHONA, B. L.) 189

CHAKRABORTY, JOGENDRA NATH– "A Method of Dispersion of Soils for Mechanical Analysis" 829

CHAKRAVARTI, S. C. (SEN, B. and)—Vernalisation of mustard . . 245

Chemical composition of raw and parboiled rices, effect of milling on (SUBRAHMANYAN, V. *et al.*) 459

——————rice varieties (SADASIVAN, V. and SREENIVASAN, A.) 807

CHINEY, S. S. (DABRAL, B. M. and)—Border effects in manurial experiments on cotton 629

—————— Micro-climatology of an irrigated cotton field in Sind 161

Chlorophyll deficiency in *Gossypium arboreum* (HUTCHINSON, J. B. and BHOLA NATH) 425

CHONA, B. L. (SUBRAMANIAM, L. S. and)—*Cephalosporium sacchari* Butl. 189

PAGE

Citrus fruit squashes, preparation and preservation of (LAL SINGH and GIRDHARI LAL) 77

Classification of soil and genetic soil survey (BASU, J. K. and SIRUR, S. S.) 637

Codling moth, distribution, status and biology of, in Baluchistan (PRUTHI, H. S.) 499

Commercial qualities of raw and parboiled rices, effect of milling on (SUBRAHMANYAN, V.). 459

Composts and soils, methods for the estimation of the furfuraldehyde yield of (ACHARYA, C. N.) 309

Cotton, border effects in manurial experiments on (DABRAL, B. M. and CHINEY, S. S.) 629

——— botany and the spinning value and hair properties of cotton lint (HUTCHINSON, J. B. and GOVANDE, G. K.) 21

——— field (irrigated) in Sind, micro-climatology of (DABRAL, B. M. and CHINEY, S. S.) 161

——— (*Gossypium arboreum*), chlorophyll deficiency in (HUTCHINSON, J. B. and BHOLA NATH) 425

———, inheritance of agricultural characters in three inter-strain crosses in (HUTCHINSON, J. B. *et al.*) 757

——— lint, hair properties of, and cotton botany and the spinning value (HUTCHINSON, J. B. and GOVANDE, G. K.) . . . 21

——— pink Boll-worm in the Punjab, studies on (HAROON KHAN, M.) . 191

——— plant, habit of, and its influence on optimum date of application of nitrogenous fertilizer (CROWTHER, F.) 617

——— root-rot in the Punjab (LUTHRA, J. C. and VASUDEVA, R. S.) . 727

Cottons (Indian), the variability of (HUTCHINSON, J. B.) . . . 570

Crop analysis and varietal improvement in Malvi *jowar* (HUTCHINSON, J. B. *et al.*) 131

Cropping and vegetative vigour of *phalsa*, effect of dormant pruning on (LAL SINGH and SHAM SINGH) 319

Crop-plant characters and their ranges of variation (HUTCHINSON, J. B. and RAMIAH, K.) 567

Crop pests (aphid), biology and general morphology of *Leucopis griseola*, an important predator of (PRUTHI, H. S. and BHATIA, H. L.) . 735

Crotalaria juncea (see " sann-hemp ") 417

CROWTHER, FRANK—" Habit of the Cotton Plant and its Influence on Optimum Date of Application of Nitrogenous Fertilizer " . 617

Cumin, *Alternaria* blight of (UPPAL, B. N. *et al.*) 49

Cydia pomonella (see " Codling moth ") 499

PAGE

D

Dabral, B. M. and Chiney, S. S.— "A Note on Border Effects in Manurial Experiments on Cotton at Sakrand during 1935-36" . 629

———————— "Micro-climatology of an Irrigated Cotton Field in Sind" 161

Das Gupta, H. P. (Subrahmanyan, V. and)— Studies on quality in rice 459

Deccan canals, soils of (Basu, J. K. and Sirur, S. S.) 637

Denitrification in the presence of sugars (Desai, S. V. and Fazal-ud-Din) 447

De, Pran Kumar and Bose, Nripendra Mohon— "A Study of the Microbiological Conditions existing in Rice Soils" . . . 487

Desai, S. V. and Fazal-ud-Din— "Denitrification in the Presence of Sugars" 447

Deshpande, R. B.— "Studies in Indian Fibre Plants, No. 5. Further Studies on the Inheritance of certain Characters in *Hibiscus sabdariffa* L." 229

Dispersion of soils for mechanical analysis (Chakraborty, J. N.) . . 829

Dormant pruning, effect of, on cropping and vegetative vigour of *phalsa* (Lal Singh and Sham Singh) 319

Dutt, N. L.; Krishnaswami, M. K. and Subba Rao, K. S.— "A Note on Seed-setting and Seed-germination in certain Sugarcanes". . 429

E

Earliness in United Provinces rices, inheritance of (Sethi, R. L. *et al.*) . 1

Euzophera punicella Moore, notes on (Pruthi, H. S.) 512

F

Fazal-ud-Din (Desai, S. V. and)—Denitrification in the presence of sugars 447

Fermentation characteristics of groundnut nodule organism (Rajagopalan, T.) 357

Fibre plants (Indian), studies in (Bose, R. D. and Misra, S. D.; (Deshpande, R. B.) . . . . 417 ; 229

Frequency of days with hail-storms in India (Ramdas, L. A. *et al.*) . 787

Fruit juices, preservation of (Lal Singh and Girdhari Lal) . . 77

—— trees, pruning of (Lal Singh and Sham Singh) 319

Furfuraldehyde yield of soils and composts, methods for the estimation of (Acharya, C. N.) 309

G

Genetic soil survey and soil classification (Basu, J. K. and Sirur, S. S.) 637

Girdhari Lal (Lal Singh and)— Preservation of fruit juices . . 77

PAGE

Gloeosporium alborubrum, causing leaf disease in *Hevea brasiliensis* (MITRA, M. and MEHTA, P. R.) 185

GOPAL RAO, S. (RAMDAS, L. A. and)—Frequency of days with hailstorms in India 787

Gossypium (see "cotton") . 21 ; 161 ; 191 ; 425 ; 570 ; 617 ; 629 ; 727 ; 757

Gossypium arboreum, chlorophyll deficiency in (HUTCHINSON, J. B. and BHOLA NATH) 425

GOVANDE, G. K. (HUTCHINSON, J. B. and)—Cotton botany and spinning value and hair properties of cotton lint 21

——————————— ——Studies in plant breeding technique 757

Green-flowering (see "phyllody") 417

Grewia asiatica (see "*phalsa*") 319

Groundnut nodule organism, studies on (RAJAGOPALAN, T.) . 331 ; 349 ; 357 ; 379

GUPTA, P. S. (SETHI, R. L. and)—Milling of rice in the United Provinces 553

H

Habit of cotton plant and its influence on optimum date of application of nitrogenous fertilizer (CROWTHER, FRANK) 617

Hail-storm days in India, frequency of (RAMDAS, L. A. *et al.*) . . 787

Hair properties and the spinning value of cotton lint and cotton botany (HUTCHINSON, J. B. and GOVANDE, G. K.) 21

HAROON KHAN, M.—"Studies on *Platyedra gossypiella* Saunders (the Pink Boll-worm of Cotton) in the Punjab, Part IV. The Incidence of *Platyedra gossypiella* in relation to Climate (1926-1931)" . . 191

Hevea brasiliensis, leaf diseases of (MITRA, M. and MEHTA, P. R.) . . 185

Hibiscus sabdariffa, inheritance of certain characters in (DESHPANDE, R. B.) 229

HUTCHINSON, J. B. and BHOLA NATH—"A Note on the Occurrence of Chlorophyll Deficiency in *Gossypium arboreum*" 425

——————— and GOVANDE, G. K.—"Cotton Botany and the Spinning Value and Hair Properties of Cotton Lint" . . . 21

———————; PANSE, V. G.; APTE, N. S. and PUGH, B. M.—"Studies in Plant-breeding Technique, III. Crop Analysis and Varietal Improvement in Malvi *Jowar* (*Andropogon Sorghum*)" . 131

——————————— and GOVANDE, G. K.—"Studies in Plant Breeding Technique, IV. The Inheritance of Agricultural Characters in three Inter-strain Crosses in Cotton" . . . 757

———————; RAMIAH, K. and Members of two special Subcommittees—"The Description of Crop-plant Characters and their Ranges of Variation, I. The Variability of Indian Cottons, II. Variability in Rice" 567

Hypodermic syringe for use with hand refractometer in sugarcane (KHANNA, K. L.) 719

PAGE

I

Imperial Agricultural Bureaux, changes in the title of 217

India, frequency of days with hail-storms in (Ramdas, L. A. *et al.*) . 787

——, some leaf diseases of *Hevea brasiliensis* new to (Mitra, M. and Mehta, P. R.) 185

——, new Asilidae from (Bromley, Stanley W.) 863

Indian cottons, the variability of (Hutchinson, J. B.) . . . 570

—— fibre plants, studies in (Bose, R. D. and Misra, S. D.) ; (Deshpande, R. B.) . . . . 417 ; 229

Inheritance of agricultural characters in three inter-strain crosses in cotton (Hutchinson, J. B. *et al.*) 757

—— certain characters in *Hibiscus sabdariffa* (Deshpande, R. B.) 229

—— earliness in the United Provinces rices (Sethi, R. L. *et al.*) 1

Inter-strain crosses in cotton, inheritance of agricultural characters in (Hutchinson, J. B. *et al.*) 757

Isolation of strain of groundnut nodule organism (Rajagopalan, T.) . 331

J

Jowar (Malvi), crop analysis and varietal improvement in (Hutchinson, J. B. *et al.*) 131

Juice extraction from sugarcane, factors influencing the (Ramji Narain and Azmat Singh) 699

—— of sugarcane, use of sub-acetate of lead in the clarification of (Khanna, K. L. and Sen, S. C.) 441

Juices of fruits, preservation of (Lal Singh and Girdhari Lal) . . 77

K

Kamat, M. N. (Uppal, B. N. and)—*Alternaria* blight of cumin . . 49

Khanna, K. L.—" A Hypodermic Syringe for Use with Hand Refractometer in Sugarcane " 719

—— and Raheja, P. C.—" Preliminary Studies in the Respiration of Sugarcane *in situ* " 253

—— and Sen, S. C.—" A Note on the Use of Sub-acetate of Lead in the Clarification of Sugarcane Juice for the Estimation of Reducing Sugars by the Potassium Ferricyanide Method " . . 441

Krishnaswami, M. K. (Dutt, N. L. and)—Seed-setting and seed-germination in certain sugarcanes 429

L

Lal Singh and Girdhari Lal—" Studies in the Preservation of Fruit Juices, I. Some Observations on the Preparation and Preservation of Citrus Fruit Squashes " 77

PAGE

LAL SINGH and SHAM SINGH—" Pruning of Fruit Trees: the Effect of Dormant Pruning on Cropping and Vegetative Vigour of *Phalsa* (*Grewia asiatica*)" 319

LANDER, P. E.; RAMJI NARAIN and AZMAT SINGH—" Soil Uniformity Trials in the Punjab, I" 271

Lead sub-acetate, use of, in the clarification of sugarcane juice (KHANNA, K. L. and SEN, S. C.) 441

Leucopis griseola, biology and general morphology of (PRUTHI, H. S. and BHATIA, H. L.) 735

Life-cycle of groundnut nodule organism (RAJAGOPALAN, T.) . . 349

Life-history of smut of sugarcane (LUTHRA, J. C. *et al.*) . . . 849

Lint (cotton), hair properties and the spinning value of, and cotton botany (HUTCHINSON, J. B. and GOVANDE, G. K.) . . . 21

LUTHRA, JAI CHAND; ABDUS SATTAR and SANDHU, SARDUL SINGH—" Life-history and Modes of Perpetuation of Smut of Sugarcane (*Ustilago scitaminaea* Syd.)" 849

——— and VASUDEVA, R. SAHAI—" Studies on the Root-rot Disease of Cotton in the Punjab, V. Confirmation of the Identity of *Rhizoctonia bataticola*" 727

M

Manures and manuring—

Habit of cotton plant and its influence on optimum date of application of nitrogenous fertilizer (CROWTHER, F.) 617

A note on border effects in manurial experiments on cotton at Sakrand during 1935-36 (DABRAL, B. M. and CHINEY, S. S.) . 629

Malvi *jowar*, crop analysis and varietal improvement in (HUTCHINSON, J. B. *et al.*) 131

Manganese in plants, estimation of (VARADARAJA IYENGAR, A. V.) . 819

Maynard-Ganga Ram Prize 555

Mechanical analysis, a method of dispersion of soils for (CHAKRABORTY, J. N.) 829

Mechanics (soil), the development of (WOOLTORTON, F. L. D.) . . 869

MEHTA, P. R. (MITRA, M. and)—Some leaf diseases of *Hevea brasiliensis*. 185

MEHTA, T. R. (SETHI, R. L. and)—Inheritance of earliness in the United Provinces rices 1

———Milling of rice in the United Provinces 553

Metabolism (intermediary) of groundnut nodule organism (RAJAGOPALAN, T.) 379

Meteorology (agricultural), (RAMDAS, L. A. *et al.*) 787

Microbiological conditions existing in rice soils (DE, P. K. and BOSE, N. M.) 487

PAGE

Micro-climatology of an irrigated cotton field in Sind (Dabral, B. M. and Chiney, S. S.) 161

Milling, effect of, on the chemical composition and commercial qualities of raw and parboiled rices (Subrahmanyan, V. *et al.*) 459

——— of rice in the United Provinces (Sethi, R. L. *et al.*) 553

——— qualities of two new Pusa wheats (Pal, B. P.) 153

Misra, S. D. (Bose, R. D. and)—Studies in Indian fibre plants 417

Mitra, M. and Mehta, P. R.—" Some Leaf Diseases of *Hevea brasiliensis* new to India " 185

Morphology (general) of *Leucopis griseola* (Pruthi, H. S. and Bhatia, H. L.) 735

Mustard, vernalisation of (Sen, B. and Chakravarti, S. C.) 245

N

Narayanan, E. S.—" A Note on *Stenobracon deesae* (Cam.), a new Parasite of the Root-borer of Sugarcane " 215

Nira Right Bank, genetic soil survey and soil classification of (Basu, J. K. and Sirur, S. S.) 637

Nitrogen (ammoniacal, nitrate and total) contents of rice soils (Bamji, N. S.) 839

Nitrogenous fertilizer, habit of cotton plant and its influence on optimum date of application of (Crowther, F.) 617

Nodule organism (groundnut), studies on (Rajagopalan, T.) 331 ; 349 ; 357 ; 379

O

Oidium hevae causing leaf spot disease in *Hevea brasiliensis* (Mitra, M. and Mehta, P. R.) 185

Oryza sativa (see " rice ") 1 ; 459 ; 487 : 553 ; 592 ; 807 ; 839

P

Paddy (see " rice ") 1 ; 459 ; 487 ; 553 ; 592 ; 807 ; 839

Pal, B. P.—" Milling and Baking Qualities of two New Pusa Wheats—an Introductory Note " 153

——— and Pushkar Nath—" Shortening the Rest Period of the Potato (*Solanum tuberosum* L.) " 777

Panse, V. G. (Hutchinson, J. B. and)—Studies in plant breeding technique 131, 757

Parboiled rices, effect of milling on the chemical composition and commercial qualities of (Subrahmanyan, V. *et al.*) 459

Patel, M. K. (Uppal, B. N. and)—*Alternaria* blight of cumin 49

Pears, soft rot of, caused by a species of *Aspergillus* (Prasad, H. H.) 549

	PAGE
Perpetuation of smut of sugarcane, mode of (LUTHRA, J. C. *et al.*)	849
Petalody (see " phyllody ")	417
Phalsa, effect of dormant pruning on cropping and vegetative vigour of (LAL SINGH and SHAM SINGH)	319
Phyllody in the flower of sann-hemp (BOSE, R. D. and MISRA, S. D.)	417
Physiology of groundnut nodule organism (RAJAGOPALAN, T.)	357 ; 379
Pink Boll-worm of cotton (*Platyedra gossypiella*) in the Punjab, studies on (HAROON KHAN, M.)	191
Plant breeding technique, studies in (HUTCHINSON, J. B. *et al.*)	131, 757
Plants, estimation of manganese in (VARADARAJA IYENGAR, A. V.)	819
Platyedra gossypiella in the Punjab, studies on (HAROON KHAN, M.)	191
Potassium ferricyanide method, use of sub-acetate of lead in the clarification of sugarcane juice for the estimation of reducing sugars by (KHANNA, K. L. and SEN, S. C.)	441
Potato breeding, present state and future development of (SALAMAN, R. N.)	119
Potato, shortening the rest period of (PAL, B. P. and PUSHKAR NATH)	777
PRASAD, H. H.—" A Note on Soft Rot of Pears caused by a Species of *Aspergillus* "	549
Pravara canals, genetic soil survey and soil classification of (BASU, J. K. and SIRUR, S. S.)	637
Preservation of fruit juices (LAL SINGH and GIRDHARI LAL)	77
Pruning of fruit trees (LAL SINGH and SHAM SINGH)	319
PRUTHI, HEM SINGH—" The Distribution, Status and Biology of Codling Moth (*Cydia pomonella* L.) in Baluchistan with Notes on some other Insects infesting Apples "	499
——————— and BHATIA, H. L.—" Biology and General Morphology of *Leucopis griseola* Fall. (Chamaemyidae, Diptera), an Important Predator of *Aphis gossypii*, and some other Aphid Pests of Crops "	735
PUGH, B. M. (HUTCHINSON, J. B. and)—Studies in plant-breeding technique	131
Punjab, root-rot disease of cotton in the (LUTHRA, J. C. and VASUDEVA, R. S.)	727
———, soil uniformity trials in the (LANDER, P. E. *et al.*)	271
———, studies on *Platyedra gossypiella* in the (HAROON KHAN, M.)	191
Pusa wheats, milling and baking qualities of (PAL, B. P.)	153
PUSHKAR NATH (PAL, B. P. and)—Shortening the rest period of the potato	777

Q

PAGE

Quarantine notification 405

Quality in rice (SUBRAHMANYAN, V. *et al.*; SADASIVAN, V. and SREENIVASAN, A.) 459; 807

R

RAHEJA, P. C. (KHANNA, K. L. and)—Respiration of sugarcane *in situ* 253

RAJAGOPALAN, T.—"Studies on Groundnut Nodule Organism, I. Isolation of Strains and Study of Culture" 331

——— II. Life-cycle of Organism" 349

——— III. Physiology of the Organism: Fermentation Characteristics" . . 357

——— IV. Physiology of the Organism—Intermediary Metabolism: Carbohydrates and Nitrogen" 379

RAMDAS, L. A.; SATAKOPAN, V. and GOPAL RAO, S.—"Frequency of Days with Hail-storms in India" 787

RAMIAH, K. (HUTCHINSON, J. B. and)—Description of crop-plant characters and their ranges of variation. 567

RAMJI NARAIN and AZMAT SINGH—"A Study of Factors influencing the Extraction of Juice from Sugarcane" 699

———(LANDER, P. E. and)—Soil-uniformity trials in the Punjab 271

Reducing sugars, use of sub-acetate of lead in the clarification of sugarcane juice for the estimation of (KHANNA, K. L. and SEN, S. C.) . 441

Refractometer (hand), a hypodermic syringe for use with, in sugarcane (KHANNA, K. L.) 719

Respiration of sugarcane (KHANNA, K. L. and RAHEJA, P. C.) . . 253

Rest period of the potato, shortening the (PAL, B. P. and PUSHKAR NATH) 777

Reviews—

Applied Mycology and Bacteriology 403

Report of the Fourth International Grassland Congress, Great Britain, July 8th to 23rd, 1937 741

The Frameworking of Fruit Trees 745

Rhizoctonia bataticola, confirmation of the identity of (LUTHRA, J. C. and VASUDEVA, R. S.) 727

Rice, milling of, in the United Provinces (SETHI, R. L. *et al.*) . . 553

—— quality in (SUBRAHMANYAN, V. *et al.*; SADASIVAN, V. and SREENIVASAN, A.) 459; 807

—— soils, the ammoniacal, nitrate and total nitrogen contents of (BAMJI, N. S.) 839

PAGE

Rice soils, microbiological conditions existing in (DE, P. K. and BOSE, N. M.) 487

——, variability in (RAMIAH, K.) 592

Rices (raw and parboiled), effect of milling on the chemical composition and commercial qualities of (SUBRAHMANYAN, V. *et al.*) . . 459

—— (United Provinces), inheritance of earliness in (SETHI, R. L. *et al.*). 1

Root-borer of sugarcane, *Stenobracon deesae*, a new parasite of (NARAYANAN, E. S.) 215

Root-rot disease of cotton in the Punjab (LUTHRA, J. C. and VASUDEVA, R. S.) 727

Rot (soft) of pears, caused by a species of *Aspergillus* (PRASAD, H. H.) . 549

Rubber plant, some leaf diseases of (MITRA, M. and MEHTA, P. R.) . 185

S

Saccharum (see "sugarcane") . . 189 ; 215 ; 253 ; 429 ; 441 ; 699 ; 719 ; 849

SADASIVAN, V. and SREENIVASAN, A.—"Studies on Quality in Rice, II. Chemical Composition of Rice Varieties" 807

Sakrand, border effects in manurial experiments on cotton at (DABRAL, B. M. and CHINEY, S. S.) 629

SALAMAN, R. N.—"The Present State and Future Development of Potato Breeding" 119

SANDHU, SARDUL SINGH (LUTHRA, J. C. and)—Life-history and modes of perpetuation of smut of sugarcane 849

Sann-hemp, phyllody and some other abnormalities in the flower of (BOSE, R. D. and MISRA, S. D.) 417

SATAKOPAN, V. (RAMDAS, L. A. and)—Frequency of days with hailstorms in India 787

Seed-germination and seed-setting in certain sugarcanes (DUTT, N. L. *et al.*) 429

SEN, B. and CHAKRAVARTI, S. C.—"Studies in Vernalisation of Mustard (A Preliminary Report)" 245

SEN, S. C. (KHANNA, K. L. and)—Use of sub-acetate of lead in the clarification of sugarcane juice 441

SETHI, B. L. (SETHI, R. L. and)—Inheritance of earliness in the United Provinces rices 1

—————— Milling of rice in the United Provinces 553

SETHI, R. L.; SETHI, B. L. and MEHTA, T. R.—"Inheritance of Earliness in the United Provinces Rices, II" 1

—————— and GUPTA, P. S.—"Observations on the Milling of Rice in the United Provinces (Supplementary Note)" 553

SHAM SINGH (LAL SINGH and)—Pruning of fruit trees 319

PAGE

Sind, micro-climatology of an irrigated cotton filed in (DABRAL, B. M. and CHINEY, S. S.) 161

SIRUR, S. S. (BASU, J. K. and)—Soils of the Deccan canals . . . 637

Smut of sugarcane, life-history and mode of perpetuation of (LUTHRA, J. C. *et al.*) 849

Soft rot of pears, caused by a species of *Aspergillus* (PRASAD, H. H.) . 549

Soil mechanics, the development of (WOOLTORTON, F. L. D.) . . . 869

—— uniformity trials in the Punjab (LANDER, P. E. *et al.*) . . . 271

Soils and composts, methods for the estimation of furfuraldehyde yield of (ACHARYA, C. N.) 309

——, dispersion of, for mechanical analysis (CHAKRABORTY, J. N.) . 829

—— of the Deccan canals (BASU, J. K. and SIRUR, S. S.) . . . 637

—— (rice), the ammoniacal, nitrate and total nitrogen contents of (BAMJI, N. S.) 839

————, microbiological conditions existing in (DE, P. K. and BOSE, N. M.) 487

Solanum (see "potato") 119; 777

Spilonota ocellana Schiff, notes on (PRUTHI, H. S.) 510

Spinning value and hair properties of cotton lint and cotton botany (HUTCHINSON, J. B. and GOVANDE, G. K.) 21

Squashes of citrus fruit, preparation and preservation of (LAL SINGH and GIRDHARI LAL) 77

SREENIVASAN, A. (SADASIVAN, V. and)—Studies on quality in rice . 807

———————— (SUBRAHMANYAN, V. and)—Studies on quality in rice 459

Stenobracon deesae, a new parasite of the root-borer of sugarcane (NARAYANAN, E. S.) 215

SUBBA RAO, K. S. (DUTT, N. L. and)—Seed-setting and seed-germination in certain sugarcanes 429

SUBRAHMANYAN, V.; SREENIVASAN, A. and DAS GUPTA, H. P.—"Studies on Quality in Rice, I. Effect of Milling on the Chemical Composition and Commercial Qualities of Raw and Parboiled Rices" . . 459

SUBRAMANIAM, L. S. and CHONA, B. L.—"Note on *Cephalosporium sacchari* Butl. (Causal Organism of Sugarcane Wilt)" . . . 189

Sugarcane, a hypodermic syringe for use with hand refractometer in (KHANNA, K. L.) 719

————, factors influencing the extraction of juice from (RAMJI NARAIN and AZMAT SINGH) 699

———— juice, use of sub-acetate of lead in the clarification of (KHANNA, K. L. and SEN, S. C.) 441

————, respiration of (KHANNA, K. L. and RAHEJA, P. C.) . . 253

———— root-borer, *Stenobracon deesae*, a new parasite of (NARAYANAN, E. S.) 215

PAGE

Sugarcane smut, life-history and mode of perpetuation of (LUTHRA, J. C. *et al.*) 849

——— wilt, *Cephalosporium sacchari* causal organism of (SUBRAMANIAM, L. S. and CHONA, B. L.) 189

Sugarcanes, seed-setting and seed-germination in (DUTT, N. L. *et al.*) . 429

Sugars, denitrification in the presence of (DESAI, S. V. and FAZAL-UD-DIN) 447

——— (reducing), use of sub-acetate of lead in the clarification of sugarcane juice for the estimation of (KHANNA, K. L. and SEN, S. C.) 441

Survey (genetic) of soil and soil classification (BASU, J. K. and SIRUR, S. S.) 637

Technique of plant breeding (HUTCHINSON, J. B. *et al.*) 757

Triticum (see " wheats ") 153

Tur-pod fly, a pest of *Cajanus Cajan* (AHMAD, T.) 63

U

Uniformity trials of soil in the Punjab (LANDER, P. E. *et al.*) . . . 271

United Provinces, milling of rice in (SETHI, R. L. *et al.*) 553

——— rices, inheritance of earliness in (SETHI, R. L. *et al.*) . 1

UPPAL, B. N. ; PATEL, M. K. and KAMAT, M. N.—" *Alternaria* Blight of Cumin " 49

Ustilago scitaminea (sugarcane smut), life-history and modes of perpetuation of (LUTHRA, J. C. *et al.*) 849

V

VARADARAJA IYENGAR, A. V.—" Estimation of Manganese in Plants " . 819

Variability in rice (RAMIAH, K.) 592

Variability of Indian cottons (HUTCHINSON, J. B.) 570

Varietal improvement in Malvi *jowar* (HUTCHINSON, J. B. *et al.*) . . 131

VASUDEVA, R. S. (LUTHRA, J. C. and)—Studies on the root-rot disease of cotton in the Punjab 727

Vegetative vigour of *phalsa*, effect of dormant pruning on (LAL SINGH and SHAM SINGH) 319

Vernalisation of mustard (SEN, B. and CHAKRAVARTI, S. C.) . . 245

W

Wheats (Pusa), milling and baking qualities of (PAL, B. P.). . . 153

Wilt of sugarcane, *Cephalosporium sacchari*, causal organism of (SUBRAMANIAM, L. S. and CHONA, B. L.) 189

WOOLTORTON, F. L. D.—" The Development of Soil Mechanics " . 869

GIPD—S3—761 IC of AR—10-4-39—800.

IMP. INST. ENT.
— LIBRARY —
23 MAY 1939
SERIAL As. 60 B
SEPARATE

ORIGINAL ARTICLES

INHERITANCE OF EARLINESS IN UNITED PROVINCES RICES, II

BY

B. L. SETHI, M.Sc. (Pb.), B.Sc. (Agri. Edin.), I.A.S.

ERRATA

INDIAN JOURNAL OF AGRICULTURAL SCIENCE VOL. 8, PART I,
FEBRUARY 1938.

Plate II (facing page 50), letterpress, line 3, *for* '4″ to 8″ celled' *read* '4- to 8-celled'.

Page 108, lines 10-11, *for* 'Imperial Bureau of Agricultural Parasitology, Helminthology Institute of Agricultural Parasitology' *read* 'Imperial Bureau of Agricultural Parasitology (Helminthology), Institute of Agricultural Parasitology'.

Page 113, line 14, *for* 'K. P. Kartha' *read* 'K. P. R. Kartha'.

sathi crosses as well. Hence this paper.

OBJECT OF STUDY

Before the data are presented we may state the aim of the *sathi* crosses, and give a brief description of the parents. The crosses were made in order to mitigate the damage caused by the fly *gundhi* (*Leptocorisa varicornis*) to the paddy crop. This fly often plays havoc with the early-ripening varieties of paddy, sucking away the juice from the developing grains so that a large percentage of them remains unfilled. The crop, consequently, suffers in yield. Sometimes the damage is as great as ninety per cent of the normal yield of the crop. While it is mostly the early varieties which suffer most, because the fly swarms most abundantly when they are in flower, sometimes the fly continues its activities till late in the season and causes a certain amount of damage to the late varieties too. No practical method has been found to control the pest, except that of trapping the flies by means of nets or thin cloth sheets, which is still not very satisfactory. The only paddy varieties which are immune to the attack of the pest are the popular broadcast *sathi* rices of these parts. Their immunity is a result of the panicle remaining enclosed in the leaf-sheath till the crop is ripe. The grain is consequently protected from the attacks of the fly. In all the other varieties the panicle emerges, sooner or later, from the sheath, and by the time fertilization of the spikelets has taken place, the whole panicle is exposed, except where the few basal spikelets remain enclosed in the sheath. Such panicles are easily attacked by the fly. The *sathi* varieties have been so named because of their short duration, which is about sixty days from sowing to ripening (*sath* meaning sixty). Their popularity may be ascribed to their short duration, to their immunity to the attacks of *gundhi*, and also perhaps to their nutritive qualities. These attributes evidently outweigh their other undesirable qualities, like poor yield and flavourless, coarse red kernels, and make the cultivators prefer them to fine rices like Bansmati and Hansraj.

It was aimed to evolve by hybridization types which possessed the desirable qualities of both the groups. The main characters under consideration were short duration, enclosed ear, heavy yield and fine grain.

The *sathi* parent employed was T 131, one of the selections made from a sample of seed obtained from the Ghazipur district. It was crossed with four of the fine-grained types, *viz.* T 1, T 3, T 7 and T 12, all of which belong to the early group of rice types of the United Provinces. They are, however, definitely later than T 131, the difference in flowering duration* being three to five weeks when grown under transplanted conditions. Besides being different in duration the parents were widely divergent in morphological characters too.

---

* Flowering duration is the number of days between sowing and commencement of flowering.

CROSSES STUDIED

Four sets of crosses were made in 1929 and they were numbered as below :—

Cross No. 17—Cross between T 131 and T 3.

Cross No. 18—Cross between T 131 and T 1.

Cross No. 19—Cross between T 131 and T 7.

Cross No. 20—Cross between T 131 and T 12.

The results of F_2 and later generations were alike in all the four cases, except in unimportant details, hence a description of any one of the crosses will suffice to illustrate the facts observed. We shall choose cross No. 18 (T 131 × T 1) for our purpose.

Cross No. 18 (T 131 × T 1)

Parents.—The parental flowering durations were as follows :—

In 1929—

T 1	89 days.
T 131	

In 1933—

T 1	87 days.
T 131	63 days.

F_1 generation.—The flowering duration of F_1 was not noted in 1930. In 1932 it was eighty-two days. The F_2 generations were grown in 1931 and 1933. The parental and F_2 mean durations are given in Table I.

TABLE I

Frequency distribution of flowering duration in parents and F_2 of cross T 131 × T 1 in 1931 and 1933

Culture	Year	Flowering duration																								
		52	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115	Total	Mean	S. D.
T 131	1931	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
T 1	,,	...	...	...	...	...	...	...	...	...	...	3	61	75	49	1	...	...	...	...	...	...	...	189	88·6	2·17
F_2	,,	...	...	...	4	...	14	2	11	3	14	14	12	14	23	21	44	41	21	6	2	...	1	247	90·8	11·20
T 131	1933	2	24	7	21	11	8	19	3	5	1	...	...	...	...	...	...	...	...	...	...	...	...	101	63·1	6·57
T 1	,,	...	...	...	...	...	...	...	...	...	...	...	3	37	40	6	...	...	...	...	...	...	...	86	89·8	1·70
F_2	,,	1	1	3	3	2	9	12	6	17	28	76	57	106	95	143	76	43	16	...	...	...	...	694	89·0	8·17

The mean of the F_2 population is almost as late as the mean of the late parent. The F_2 shows a higher standard deviation than the parents. Again, of the two parents, T 131 shows a very much higher standard deviation. This is due perhaps to the following reason :—

T 131 being very early, some of its seedlings sometimes put forth an earhead even in the nursery. Even when they do not, they do so soon after transplanting. Such seedlings cannot be said to have 'flowered' because they first proceed with fresh vegetative activity before entering the flowering phase. The premature appearance of the ear in such cases is only an expression of their 'periodicity'. Since the flowering date noted is the one on which the first panicle of a plant is observed, it is apparent that the flowering in such seedlings will be noted before its proper time, while in other seedlings not exhibiting periodicity it will be noted at a later period. This will obviously result in a widening of the observed flowering range. Such a disturbance in flowering was not observed in T 1.

F_2 generation.—The F_2 range extends from the lower extreme of the early parent to appreciably beyond the upper extreme of the late parent. The range is continuous, there being no grouping into distinct classes as was the case in the economic crosses already described [Sethi, Sethi and Mehta, 1936]. Although the flowering records were taken daily, the durations were combined into three-day classes for preparing Table I. Difficulty was felt in noting down the exact flowering date in the case of plants in which the panicles remained enclosed in the sheath. In such cases the swollen appearance of the sheath containing the developing panicle served as a useful guide. Accuracy of observation came with experience, and where the observation was doubtful the roughness of touch, when the panicle was felt between the fingers, was a safe index of flowering.

The continuity of the F_2 range suggests the operation of multiple factors in the cross. It has not been possible to estimate the number of factors responsible for the inheritance of flowering duration in this cross, although from the nature of segregation it is surmised that the number must be large.

F_3 generations.—The selection of F_2 plants in 1931 as parents for the F_3 generation was done more for economic ends than for completing academic studies. Hence some of the earliest F_2 plants, being poor in their various attributes, were discarded. In 1934, however, the F_3 generation contained certain families which came from some of the earliest plants. The seedlings of the F_3 generation grown in 1932 were first raised in pots (Plate I). The total number of families of all the crosses studied was 516, but in the cross under consideration this generation consisted of ninety-five families only. The distribution of flowering duration of each of these families has been presented in detail in an Appendix. A summary of the data is given in Table III. This table gives the frequency distributions of 13,959 F_3 plants arranged according to the parental durations. To arrive at such an arrangement the frequency distributions of the families, whose parental flowering durations were more or less identical, were combined together. The distributions have been presented in rows. Thus, the distribution given in the fourth row is obtained by totalling the distributions of eight F_3 families (Table II, column 1), the parents of each of which showed the same duration, *viz.* seventy-three days (column 2). Column 3 gives the average mean durations of the F_3 families. It will be seen that the figures in columns 2 and 3, *viz.* the F_2 parental durations and the F_3 mean durations tend to vary together. This tendency has been represented in the table by the marks (*) and (†), the former representing the F_2 parental duration class and the latter the F_3 mean duration class. It will be seen that the two marks show a tendency to run together. This tendency can be expressed by the correlation coefficient between the two durations. This is $+0\cdot726$, which is high and significant. In other words, the F_2 plants of longer durations have given F_3 families of correspondingly longer durations. Or, to express the fact differently, the variations observed in the F_3 durations were, in a great measure, genetic.

The very early and the very late F_2 plants (Table II) give F_3 progenies whose mean durations have shown some regression toward the general mean. This is partly so because the extreme plants, as usual in every progeny, do not completely represent the genetic nature of the parent but are, to a marked extent, the expression of non-genetic variation. The regression in some of the early families may also be ascribed to the periodicity of their parental F_2 plants which may have been noted as flowered when they put forth a premature short earhead.

A general view of the nursery (pots) in which the F_3 seedlings were raised in 1932

TABLE II

Frequency distribution of flowering durations of 13,959 F_3 plants arranged according to the parental F_2 durations

No. of F_3 families	F_2 duration	F_3 average mean	Flowering duration in days																					Total	Average S. D.
			55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115		
3	61	78·3	...	2	2*	6	10	15	15	61	86†	64	18	11	13	...	...	...	...	...	...	...	...	303	5·33
4	67	80·0	2	4	2	16	20*	57	45	54	118†	116	...	163	15	2	4	...	...	3	...	...	...	621	4·80
1	70	84·0	...	...	...	...	...	*	...	5	40	40	†	38	17	2	4	...	...	...	...	...	...	146	5·02
8	73	84·8	...	...	...	...	...	2	7*	38	202	155	†	370	47	13	17	7	...	5	...	...	...	863	4·33
10	79	83·3	...	1	...	...	2	1	13	53	443*	431†	60	287	78	44	10	4	2	3	...	...	...	1,432	4·05
14	85	84·6	...	...	1	...	1	9	13	40	405	478	71*†	700	192	63	38	11	1	2	...	...	...	2,025	4·56
6	88	86·5	...	...	...	...	...	2	1	17	143	149	1	*†407	130	26	32	8	1	1	...	...	...	918	4·34
6	91	86·3	...	...	...	...	...	...	6	26	153	232	34†	273	102*	61	60	7	1	2	1	...	...	958	5·07
6	94	86·3	...	...	...	...	...	...	7	39	192	201	†	346	103	37*	80	19	6	3	...	...	..	1,033	5·82
16	97	90·7	...	...	...	...	...	1	...	15	72	197	71	791	690†	246	381*	168	19	19	1	...	...	2,671	4·48
10	100	95·4	...	...	...	1	1	1	1	...	17	45	3	132	249	85†	258	486*	56	31	2	...	...	1,368	4·64
8	103	94·6	...	...	...	...	...	...	...	1	21	26	21	121	285	110†	146	198	9*	90	89	...	8	1,125	4·24
2	106	96·0	...	...	...	...	...	...	1	...	11	22	...	79	41	39	42†	90	12	*	1	...	...	338	5·46
1	115	84·0	...	...	...	...	...	1	...	31	42	46	†	8	3	...	...	7	...	20	...	...	*	158	9·73
																								13,959	

* F_2 duration
† F_3 mean duration

Each figure in the last column of Table II is the average of the standard deviations of the F_3 families represented in that row. Now, each of these averages is based only upon a small number of families. Moreover it gives no indication of the magnitude of the various standard deviations of which it is an average. To calculate the standard errors of figures from such small samples would serve no purpose. Hence they have not been given in the table. A statistical comparison between the figures is, therefore, out of question. Only a study of a very much larger number of F_3 families in the cross could have given further statistical information. However, the extreme sterility of F_1 and F_2 plants resulted in our getting very few plants to choose from. This fact, along with the rarity of plants of economic worth, and our desire to limit the selections to economic needs only, resulted in our limiting the studies to ninety-five families. Studies of this nature always involve an examination of a larger number of plants, and every additional statistical information gained seems to be at the expense of a disproportionately large amount of labour. These practical difficulties cannot be ignored. We cannot, therefore, always satisfy the statistical needs in hybridization studies. However, the difficulties mentioned here need not deter us from roughly comparing the average standard deviation figures given in Table II. We find that these averages do not vary in a definite order. The families from F_2 parents of intermediate durations show as high standard deviations as the families from F_2 parents of extreme durations. That is, the intermediate F_2 plants are not more heterozygous in flowering duration than the plants of extreme durations--a fact which appears to contradict the accepted concepts of the inheritance of quantitative characters. This anomaly can be explained on the assumption that the two parent varieties differed in many factors from each other with the result that the F_2 population grown was not sufficiently large to include more than a very limited number of homozygous individuals at the extremes.

In selecting for F_3 these plants were almost all excluded on account of their meagre representation. Consequently the extreme plants selected were not very different from the more intermediate plants, so far as heterozygosity is concerned, with the result that similar standard deviations were observed in the two cases.

Another table (Table III) is given showing the F_3 data as in Table II, but with the frequency distributions arranged according to the mean durations of the F_3 families.

TABLE III

Frequency distribution of flowering durations of 13,959 F_3 plants arranged according to the mean durations of F_3 families

of F_3 cultures	Av. F_2 duration	F_3 mean	Flowering duration in days																					Total	Average S. D.
			55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115		
1	67·0	70	...	3	1	15	20*	57†	38	41	4	3	...	...	...	...	...	...	...	...	...	...	...	182	4·30
2	61·0	76	...	2	2*	6	10	11	15	54†	66	43	2	11	1	...	...	...	...	...	...	...	...	223	5·45
3	80·7	79	...	...	...	...	...	...	2	22	179†	54*	36	19	29	5	13	1	...	...	...	...	...	360	3·85
20	79·9	82	...	...	1	...	1	13	22	153	991*	943†	90	605	115	19	14	1	1	4	1	...	...	2,974	4·25
16	84·2	85	2	2	1	1	2	3	23	72	395	561	34*†	990	146	62	32	16	2	27	...	...	...	2,371	5·07
20	89·3	88	...	...	...	...	...	3	6	33	260	430	22	*† 1269	473	165	162	51	15	7	...	...	...	2,896	4·92
16	96·2	91	...	...	...	...	...	1	1	11	38	120	44	614	858†	259	287*	120	16	18	1	...	...	2,388	4·50
7	100·0	94	...	...	...	1	1	1	1	...	23	39	...	137	204	75†	152	236*	25	8	2	...	...	905	5·79
6	100·5	97	...	...	...	...	...	...	1	...	11	26	3	139	97	100	306†	239*	36	25	1	...	...	984	6·68
3	101·7	100	...	...	...	...	...	...	...	...	...	1	...	1	4	31	97	332†	13*	16	...	...	...	495	2·28
1	103·0	106	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	7	*	74†	89	...	8	181	2·79
																								13,959	

* F_2 duration
† F_3 mean duration

From the Appendix it will be seen that none of the F_3 families was as early as T 131. This may be interpreted as being due to the fact that the earliest F_2 plants, being of little promise, were not selected for the next generation—a fact already mentioned (p. 5). To see if this was really the case another F_3 generation was raised in 1934. Even in this generation no family possessed the earliness of T 131 although many were earlier than T 1. Table IV gives the frequency distributions of some of the families.

The different families differ greatly in their flowering periods (*i.e.*, the interval between the flowering of the earliest and the latest plants in a family). For, whereas some of them possess flowering periods of over a month (*e.g.*, families 12, 86 and 110), others show considerably smaller periods (*e.g.*, families 137, 168 and 470). The lower extremity of T 131 is not reached by any F_3 family, but the upper extreme of the late parent (T 1) is easily transgressed by some of the families. The variations shown by the F_3 families suggest the operation of genetic factors in such a way as to make possible the isolation, in later generations, of strains of widely different mean durations, some appreciably earlier and some definitely later than T 1, although none as early as T 131.

Some of the conclusions which emerge from the above facts may be given here. One of them is that crossing may open up unsuspected or unforeseen possibilities. Because, whereas the crossing of a type like T 1 with an earlier type like T 131 would normally be expected to throw out in the F_3 generation families of parental and intermediate durations, it would be more or less an unforeseen, though not an unusual, event to get families appreciably later even than the late parent. But this was what actually happened, and was apparently due to a recombination of genetic factors. Further, much of the variation existing in F_2 was genetic, as is evidenced by the fact that the F_3 mean durations tend to vary with the parental F_2 durations. In some cases, however, such a relationship is absent, as in the case of F_3 39 (Table IV), where the mean duration is eighty-seven days while the parental F_2 duration was ninety-six days. Similarly certain other families also show disparities between the F_2 and F_3 mean durations. The disparity in the F_2 and the F_3 mean durations in such cases only serves to illustrate the fact that the characters of an F_2 plant are not solely the expression of its genetic constitution but a resultant of environmental influences too. Thus the extreme earliness of F_2 parent which gave rise to the F_3 207 was not inherited because it was, to a great extent, environmental. It is impossible in an F_2 generation to judge how much of the variation observed is environmental and how much is genetic. Hence, while making selections in F_2, one has to constantly bear in mind the fact that due to the operation of environment, F_3 families may not conform to the expectations based upon the performance of the F_2 plants. It is useful, therefore, to make a liberal selection of F_2 plants in order to secure a reasonably good number of desired F_3 families.

F_4 and later generations.—Observations on flowering were continued in the F_4 and later generations. In these generations plant-to-plant study was not pursued, the observations consisting of the recording of the numbers of flowered plants in each culture at intervals of three days. This yielded information not only on the rate of progress of flowering in each culture (and consequently its 'purity') but also on the mean flowering duration and on the flowering period (*i.e.*, the number of days between the beginning and finish of flowering). Such an information is necessary for a proper estimate of the hybrid populations being dealt with, because it tells us not only how the homozygosity of the cultures is increasing, but also how far the desired earliness has been secured. The relevant information of this nature obtained from a study of the later generations of cross 18 is described here.

The F_4 population consisted of 160 cultures. Forty-six of these had sufficiently short flowering periods to mark them off as 'pure'. (The purity has been judged according to whether or not the culture finished its flowering within thirteen days after starting it. This period was chosen as the index on the strength of pure-line data and of field observations with the hybrids.) Of the forty-six cultures only twenty, *i.e.*, 12·5 per cent of the total number of F_4 cultures, were as early as, or earlier than, T 1. The rest of the cultures (114 in number) were impure. These were of different durations, the means being identical with that of T 1 in some cases and being earlier and later in the other cases. These facts are diagrammatically represented in Fig. 1. Each dot represents a culture, and the scatter of the dots represents the distribution of the cultures with respect to their mean durations and their flowering periods. The arrow marked on the axis just before figure 90 indicates that cultures lying to the left of this arrow have shorter mean durations than T 1. The arrow on the ordinate between 10 and 15 marks off 'pure' from 'impure' cultures. The two lines which are extensions from the arrows and which meet at right angles among the dots mark off cultures, which are pure and at the same time earlier than T 1, from the rest of the cultures. In F_3 the number of such cultures was only seven out of a total of ninety-five, *i.e.*, 7·4 per cent.

TABLE

Frequency distribution of flowering durations of parents

Culture	Year	Parental duration	51 52	53 54	55 56	57 58	59 60	61 62	63 64	65 66	67 68	69 70	71 72	73 74	75 76
T 131 .	1933	..	2	1	23	2	9	17	10	4	5	12	7	3	5
T 1 .	1933	..	..	..	..	..	..	..	..	..	..	..	..	..	..
F_2 . .	1933	..	1	0	1	3	1	2	1	3	7	8	6	4	15
F_3 207 .	1934	57	..	..	..	..	..	4	4	5	14	30	20	10	13
F_3 253 .	1934	61	..	..	..	..	..	..	..	4	7	13	13	18	14
F_3 100 .	1934	68	..	..	..	..	..	..	1	1	..	..	3	10	13
F_3 340 .	1934	69	..	..	..	..	..	..	..	..	1	2	1	2	5
F_3 474 .	1934	74	..	..	..	..	5	4	..	2	2	11	10	8	8
F_3 12 .	1934	77	..	..	..	..	1	2	1	1	2	2	..	4	7
F_3 137 .	1934	78	..	..	..	..	..	..	..	..	..	..	..	9	7
F_3 488 .	1934	80	..	..	..	..	..	..	..	..	..	..	1	..	5
F_3 22 .	1934	82	..	..	..	..	..	..	..	..	..	..	..	..	1
F_3 470 .	1934	84	..	..	..	..	..	..	..	..	..	..	..	..	..
F_3 353 .	1934	86	..	..	..	..	..	..	..	..	..	..	..	..	1
F_3 179 .	1934	87	..	..	..	..	..	..	..	..	..	..	..	..	1
F_3 168 .	1934	88	..	..	..	..	..	..	..	..	..	..	..	1	5
F_3 110 .	1934	90	..	..	..	..	..	1	..	..	1	1	6	8	11
F_3 86 .	1934	93	..	..	..	..	..	..	..	..	..	..	..	..	1
F_3 43 .	1934	94	..	..	..	..	..	..	..	..	..	..	..	..	1
F_3 39 .	1934	96	..	..	..	..	..	..	..	..	..	..	..	..	..
F_3 133 .	1934	99	..	..	..	..	..	..	..	..	..	..	..	..	..

IV

and F_2 *in 1933 and of eighteen* F_3 *families in 1934*

77 78	79 80	81 82	83 84	85 86	87 88	89 90	91 92	93 94	95 96	97 98	99 100	101 102	103 104	105 106	No.	Mean
0	1	..	..	..	..	..	..	..	..	..	..	..	..	..	101	63·07
..	..	..	..	3	16	42	19	5	1	..	..	..	..	..	86	89·78
9	21	41	42	50	85	57	59	94	89	36	37	9	13	..	694	89·03
6	4	3	..	..	..	..	..	..	..	..	..	..	..	..	113	71·08
15	2	9	3	1	..	..	..	1	..	..	..	..	..	..	100	74·32
32	5	27	22	8	2	..	..	..	..	..	..	..	..	..	124	79·31
12	6	28	20	13	8	4	2	..	..	..	..	..	..	..	104	81·87
13	1	4	26	1	2	..	..	..	..	..	..	..	..	..	97	75·52
18	20	21	11	5	3	2	1	1	..	..	..	..	..	..	102	79·19
22	5	60	7	3	..	..	..	..	..	..	..	..	..	..	113	79·85
21	26	15	48	3	3	..	..	..	..	..	..	..	..	..	122	81·09
1	9	26	35	19	13	6	5	4	1	..	..	..	..	..	120	84·47
..	6	22	21	25	8	9	3	3	..	..	..	..	..	..	97	84·76
..	1	4	19	19	32	13	13	..	5	..	..	..	..	..	107	87·13
7	9	29	21	10	16	..	4	4	..	..	..	..	..	..	101	83·62
27	21	37	12	8	1	..	..	..	..	..	..	..	..	..	112	80·38
16	4	12	9	12	9	10	4	6	2	..	4	2	..	..	118	82·72
9	7	5	5	4	2	8	8	11	17	12	3	10	2	2	106	91·25
10	16	6	10	8	19	10	16	5	5	5	3	2	..	..	116	86·95
..	..	2	18	14	48	9	11	4	5	1	..	..	..	..	112	87·71
..	1	..	2	..	..	..	7	3	2	13	15	48	11	16	118	100·14

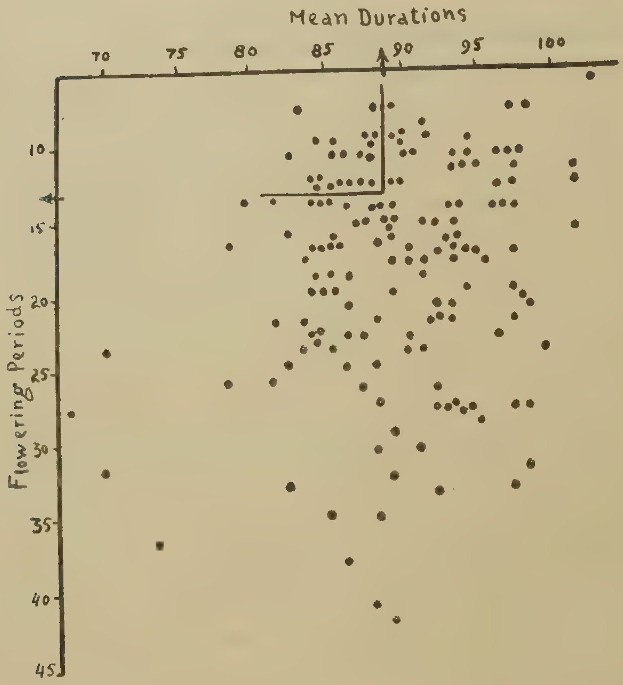


FIG. 1. Mean flowering durations and flowering periods in 160 F_4 cultures of cross 18 (T 131 × T 1) in 1933.

Selections for F_5 were made both from pure and impure cultures. Some of the latter gave pure cultures in the F_5. The increase in the number of pure cultures, as well as the narrowing of the flowering periods of impure cultures, resulted in the reduction of the mean flowering period of 18·11 days in F_4 to 13·11 days in F_5. The percentage of pure cultures was also raised from 29·4 per cent to 67·3 per cent. The number of cultures which were both pure and as early as, or earlier than, T 1 had increased to 53·5 per cent of the total number of cultures in F_5.

In F_6 the flowering period was further reduced to 9·4 days, the percentage of pure cultures being as high as ninety-five. That is, nearly all the cultures were pure in F_6.

Similar conditions prevailed in the other *sathi* crosses as well. A large number of the cultures of short and desirable durations have thus been bred.

SUMMARY

The results of a study of earliness made in four rice crosses with *sathi* rice as one of the parents have been described. Data up to the F_6 generation have been presented. The frequency distribution of flowering duration in F_2 was continuous and extended from the lower extreme of the early parent to well beyond the upper extreme of the later parent. The F_2 durations tended to be reproduced in the F_3 generation, although environmental influences exercised considerable control over the flowering of certain plants. The standard deviations of the flowering durations of the different F_3 families did not exhibit any relation to the corresponding mean values. The inheritance was governed by several cumulative genes. There was a rapid increase in homozygosity till in the F_6 generation almost all the hybrid cultures had become ' pure '.

ACKNOWLEDGMENTS

Our acknowledgments are due to the Imperial Council of Agricultural Research whose financial help rendered possible the completion of the studies described above.

REFERENCE

Sethi, R. L.; Sethi, B. L. and Mehta, T. R. (1936). *Ind. J. Agric. Sci.* **6**, 1246-1273.

APPENDIX

Frequency distributions of flowering duration of F_3 families arranged according to parental F_2 durations—Cross No. 18 (T 131 × T 1), 1932

F_2	F_3	F_2 duration	F_3 mean	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115
18/1EN	5	61	82	...	...	...	...	...	4	...	7	20	21	16	...	12	...	...	...	...	...	...	...	...
,,	18	61	76	...	...	1	...	6	5	3	13	15	11	2	...	...	...	...	...	...	...	...	...	...
,,	60	61	77	...	2	1	6	4	6	12	41	51	32	...	11	1	...	...	...	...	...	...	...	...
				...	2	2	6	10	15	15	61	86	64	18	11	13	...	...	...	...	...	...	...	...
,,	50	67	71	...	3	1	15	20	57	38	41	4	3	...	...	...	...	...	...	...	...	...	...	...
,,	90	67	84	2	1	1	1	...	...	6	5	26	48	...	103	13	...	4	...	...	...	...	...	...
,,	175	67	82	...	...	...	...	...	...	1	8	73	40	...	41	2	1	...	...	...	3	...	...	...
,,	184	67	83	...	...	...	...	...	...	...	...	15	25	...	19	...	1	...	...	...	...	...	...	...
				2	4	2	16	20	57	45	54	118	116	...	163	15	2	4	...	...	3	...	...	...
18/3	12	69	84	...	...	...	...	...	...	...	5	40	40	...	38	17	2	4	...	...	...	...	...	...
18/1EN	179	73	82	...	...	...	...	...	...	1	2	50	13	...	22	...	...	...	...	...	...	...	...	...
18/2	5	73	88	...	...	...	...	...	...	...	...	2	11	...	66	8	7	...	4	...	...	...	...	...
,,	6	73	87	...	...	...	...	...	...	...	...	...	23	...	80	16	1	...	...	...	...	...	...	...
18/1EN	77	74	81	...	...	...	...	...	...	...	6	26	12	...	14	...	...	...	...	...	...	...	...	...
,,	92	74	85	...	...	...	...	...	...	2	4	26	3	...	76	...	...	...	...	...	...	...	...	...
,,	188	74	84	...	...	...	...	...	...	...	...	47	51	...	57	1	1	...	...	...	3	...	...	...
18/3	1	74	90	...	...	...	...	...	1	1	3	4	4	...	31	13	4	16	3	...	2	...	...	...
,,	11	74	81	...	...	...	...	...	1	3	23	47	38	...	24	9	...	1	...	...	...	...	...	...
				...	...	...	...	...	2	7	38	202	155	...	370	47	13	17	7	...	5	...	...	...

18/1EN	3	79	88	...	...	...	...	...	...	...	...	...	12	21	...	38	7	...	...	...	...	...	...	...
,,	10	79	81	...	...	...	...	...	1	...	12	67	77	20	...	4	2	...	...	...	...	...	...	...
,,	11	79	82	...	...	...	...	...	...	...	7	38	107	19	...	17	1	...	...	...	...	...	...	...
,,	35	79	80	...	...	...	...	...	...	2	20	33	14	...	10	2	...	...	...	...	...	...	...	...
,,	94	79	85	...	...	...	...	...	...	...	...	26	22	...	61	1	...	...	...	...	...	...	...	...
,,	120	79	82	...	...	...	...	...	...	...	4	63	52	...	42	2	...	...	1	...	...	...	...	...
,,	125	79	80	...	...	...	...	...	...	...	1	137	15	...	9	...	...	...	...	...	...	...	...	...
,,	159	79	83	...	...	...	...	...	...	...	...	41	60	...	41	...	1	...	...	...	...	...	...	...
,,	174	79	86	...	1	...	...	2	...	11	4	24	15	...	52	...	28	4	2	2	3	...	...	...
18/3	14	79	86	...	...	...	...	...	...	...	5	14	57	...	72	14	5	6	1	...	...	...	...	...
				...	1	...	...	2	1	13	53	443	431	60	287	78	44	10	4	2	3	...	...	...
18/1EN	17	84	83	...	...	...	...	...	...	...	4	31	35	35	...	8	2	...	...	...	...	...	...	...
,,	19	84	80	...	...	...	...	...	...	...	1	9	25	36	...	27	5	13	1	...	...	...	...	...
,,	40	84	87	...	...	...	...	...	...	...	4	8	26	...	59	41	6	1	...	...	...	...	...	...
,,	43	84	83	...	...	...	...	...	...	...	5	52	71	...	27	13	...	...	...	...	...	...	...	...
,,	67	84	83	...	...	...	...	...	...	...	4	42	65	...	39	10	2	1	...	...	...	...	...	...
,,	70	84	85	...	...	...	...	...	...	...	...	27	40	...	61	3	1	1	...	...	...	...	...	...
,,	75	84	85	...	...	...	...	...	...	...	...	13	41	...	83	1	...	...	...	...	...	...	...	...
,,	103	84	83	...	...	...	...	...	...	...	4	56	38	...	45	1	...	...	...	...	...	...	...	...
,,	138	84	89	...	...	...	...	...	...	...	...	9	18	...	67	26	20	6	4	...	...	...	...	...
,,	142	84	82	...	...	1	...	1	7	9	6	34	13	...	48	4	4	...	...	...	...	...	...	...
,,	173	84	83	...	...	...	...	...	...	1	9	81	44	...	60	15	2	4	...	1	...	...	...	...
18/2	16	85	86	...	...	...	...	...	...	...	...	9	34	...	98	4	...	1	...	...	...	...	...	...
18/1EN	108	86	87	...	...	...	...	...	...	...	1	21	15	...	54	16	10	6	2	...	...	...	...	...
,,	158	86	88	...	...	...	...	...	2	3	2	13	13	...	59	23	11	5	4	...	2	...	...	...
				...	...	1	...	1	9	13	40	405	478	71	700	192	63	38	11	1	2	...	...	...

APPENDIX—*contd.*

F_2	F_3	F_3 duration	F_3 mean	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115
18/1EN	102	87	87	...	...	...	...	...	...	...	1	33	20	...	69	18	9	4	6	1	...	...	...	...
,,	167	87	82	...	...	...	...	...	...	...	6	59	58	...	40	...	...	1	...	...	1	...	...	...
18/2	2	87	89	...	...	...	...	...	...	...	...	...	7	...	100	43	3	10	...	...	...	...	...	...
,,	4	88	90	...	...	...	...	...	...	...	2	4	8	1	38	32	13	14	2	...	...	...	...	...
18/3	19	88	85	...	...	...	...	...	2	1	8	24	35	...	46	34	...	...	...	...	...	...	...	...
18/1EN	96	89	86	...	...	...	...	...	...	...	...	23	21	...	144	3	1	3	...	...	...	...	...	...
				...	...	...	...	...	2	1	17	143	149	1	407	130	26	32	8	1	1	...	...	...
18/1EN	181	90	88	...	...	...	...	...	...	...	...	10	29	...	69	4	21	5	1	1	1	...	...	...
,,	185	90	88	...	...	...	...	...	...	3	5	22	11	...	46	10	14	18	3	...	1	...	...	...
18/2	8	90	83	...	...	...	...	...	...	3	17	74	58	...	61	6	2	2	...	...	...	1	...	...
18/1EN	45	91		...	...	...	...	...	...	...	4	8	14	...	49	42	17	32	1	...	...	...	...	...
,,	9	92	86	...	...	...	...	...	...	...	...	10	46	34	...	37	7	3	2	...	...	...	...	...
,,	39	92	83	...	...	...	...	...	...	...	...	29	74	...	48	3	...	...	...	...	...	...	...	...
				...	...	...	...	...	...	6	26	153	232	34	273	102	61	60	7	1	2	1	...	...
,,	78	93	89	...	...	...	...	...	...	...	...	9	29	...	81	29	11	19	1	...	1	...	...	...
18/3	4	93	85	...	...	...	...	...	...	...	6	18	30	...	55	15	1	...	...	...	...	...	...	...
,,	6	93	81	...	...	...	...	...	...	4	29	93	42	...	34	9	1	5	...	...	...	...	...	...
,,	9	93	89	...	...	...	...	...	...	...	...	14	41	...	56	32	...	42	5	2	...	...	...	...
18/1EN	161	95	88	...	...	...	...	...	...	...	...	30	27	...	54	18	8	8	9	4	1	...	...	...
,,	177	95	86	...	...	...	...	...	...	3	4	28	32	...	66	...	16	6	4	...	1	...	...	...
				...	...	...	...	...	...	7	39	192	201	...	346	103	37	80	19	6	3	...	...	...

18/1EN	14	96	92	...	...	...	...	...	...	...	1	3	13	22	...	58	9	37	10	5	6	1	...	...
”	20	96	88	...	...	...	...	...	...	...	...	6	18	27	...	21	14	9	3	1	...	...	...	...
”	33	96	87	...	...	...	...	...	...	...	...	12	24	...	159	19	1	...	...	...	...	...	...	...
”	100	96	88	...	...	...	...	...	...	...	...	13	12	...	66	22	8	13	2	...	...	...	...	...
18/3	10	97	93	...	...	...	...	...	...	...	...	...	4	...	24	60	...	53	7	1	...	...	...	...
”	13	97	90	...	...	...	...	...	...	...	...	...	...	...	56	146	3	3	...	...	...	...	...	...
18/1EN	26	98	88	...	...	...	...	...	1	...	13	17	31	22	...	71	23	13	5	1	1	...	...	...
”	32	98	91	...	...	...	...	...	...	...	...	...	17	...	53	39	26	23	3	1	1	...	...	...
”	66	98	87	...	...	...	...	...	...	...	1	2	39	...	112	12	1	5	3	1	...	...	...	...
”	73	98	90	...	...	...	...	...	...	...	...	...	...	...	99	60	13	5	1	...	2	...	...	...
”	79	98	91	...	...	...	...	...	...	...	...	...	...	...	61	50	17	9	10	1	...	...	...	...
”	87	98	92	...	...	...	...	...	...	...	...	2	13	...	66	23	4	9	39	1	...	...	...	...
”	112	98	94	...	...	...	...	...	...	...	...	7	4	...	19	14	25	...	47	3	2	...	...	...
”	162	98	92	...	...	...	...	...	...	...	...	8	21	...	36	...	59	...	29	...	7	...	...	...
18/2	15	98	96	...	...	...	...	...	...	...	...	...	...	...	8	24	28	171	5	2	...	...	...	...
18/3	23	98	92	...	...	...	...	...	...	...	...	2	1	...	32	71	15	31	4	2	...	...	...	...
				...	...	...	...	...	1	...	15	72	197	71	791	690	246	381	168	19	19	1	...	...
18/1EN	38	100	93	...	...	...	1	1	1	1	...	6	7	...	25	31	11	42	9	14	1	...	...	...
”	143	100	97	...	...	...	...	...	...	...	...	...	3	...	33	7	2	8	84	...	24	...	...	...
”	146	100	95	...	...	...	...	...	...	...	...	8	17	...	17	6	...	3	87	...	2	...	...	...
”	22	101	97	...	...	...	...	...	...	...	...	...	...	3	...	20	9	20	27	20	1	...	...	...
”	98	101	99	...	...	...	...	...	...	...	...	...	...	...	...	...	6	42	126	...	...	...	...	...
”	104	101	93	...	...	...	...	...	...	...	...	2	5	...	27	10	21	15	14	1	...	2	...	...
”	126	101	96	...	...	...	...	...	...	...	...	...	1	...	19	5	22	65	33	2	...	...	...	...
”	133	101	99	...	...	...	...	...	...	...	...	...	1	...	1	1	7	36	102	13	...	...	...	...
18/3	24	101	94	...	...	...	...	...	...	...	...	...	...	...	7	43	5	21	3	6	3	...	...	...
”	36	101	91	...	...	...	...	...	...	...	...	1	11	...	3	126	2	6	1	...	...	...	...	...
				...	...	...	1	1	1	1	...	17	45	3	132	249	85	258	486	56	31	2	...	...

APPENDIX—*concld.*

F_2	F_3	F_2 duration	F_3 mean	55	58	61	64	67	70	73	76	79	82	85	88	91	94	97	100	103	106	109	112	115
18/3	8	102	92	...	...	...	...	...	...	...	...	...	...	...	21	122	3	31	3	...	...	...	...	...
,,	22	102	92	...	...	...	...	...	...	...	...	...	7	...	28	18	5	18	8	3	...	...	...	...
,,	27	102	89	...	...	...	...	...	...	...	...	15	6	...	13	44	2	4	1	3	...	...	...	...
18/1EN	16	103	92	...	...	...	...	...	...	...	...	...	3	21	...	54	19	41	1	2	...	...	...	...
,,	55	103	107	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	7	...	74	89	...	8
,,	64	103	95	...	...	...	...	...	...	...	...	...	2	...	18	40	13	18	69	...	...	...	...	...
,,	139	103	99	...	...	...	...	...	...	...	...	...	...	...	...	3	18	19	104	...	16	...	...	...
,,	171	103	91	...	...	...	...	...	...	...	1	6	8	...	41	4	50	12	5	1	...	...	...	...
				...	...	...	...	...	...	...	1	21	26	21	121	285	110	146	198	9	90	89	...	8
,,	74	106	96	...	...	...	...	...	...	1	...	11	22	...	60	27	13	27	26	3	...	...	...	...
,,	101	106	96	...	...	...	...	...	...	...	...	...	...	...	19	14	26	15	64	9	...	1	...	...
				...	...	...	...	...	...	1	...	11	22	...	79	41	39	42	90	12	...	1	...	...
,,	68	116	84	...	...	...	...	...	1	...	31	42	46	...	8	3	...	...	7	...	20	...	...	...

COTTON BOTANY AND THE SPINNING VALUE AND HAIR* PROPERTIES OF COTTON LINT

BY

J. B. HUTCHINSON

AND

G. K. GOVANDE

Institute of Plant Industry, Indore, Central India

(Received for publication on 31st December 1936)

CONTENTS

		Page
I.	Introduction	21
II.	Data	22
III.	Discussion	42
IV.	Summary	46
V.	Acknowledgments	46
	References	47

I. Introduction

The problem of estimating the spinning value of small quantities of cotton has been studied in detail by technological research workers, and has led to the development and standardisation of the spinning test on 10-lb. samples of lint. Parallel with the development of spinning tests, the physical properties of the cotton hair and their effects on spinning value have been studied. The present position with regard to spinning tests is summarised by Ahmad [1932], and in an Editorial [1932] in the *Empire Cotton Growing Review.* The state of knowledge concerning the relationship between hair properties and spinning value is summarised by Turner and Underwood [1934].

The technological interest of spinning values and hair properties has naturally been paramount in the minds of those who have designed and conducted the tests, and discussed the results. For this reason, and on account of the very unsatisfactory state into which the botanical classification of cotton had fallen, the information available in technological literature is usually classified according to the trade names, or by the places of origin, of the varieties studied, and little or no account has been taken of botanical differences.

---

* In technological literature, cotton lint is usually described as 'fibre'. Botanically, fibres are multicellular strands of tissue, and unicellular structures, such as cotton lint, are hairs. While we have no doubt that cotton will continue to be classified as a fibre, in the present paper we prefer to retain the botanical terminology.

The recent revision of the classification of the cottons of Asia and Africa by Hutchinson and Ghose [1937, 2] has made it possible to study the magnitude of the differences between the different cultivated species, varieties, and forms in hair characters and spinning properties.

II. DATA

The technological material studied is that given by Turner and Venkataraman [1933], supplemented by similar material abstracted from the Technological Reports of the Director of the Technological Laboratory, Bombay, on Standard Indian Cottons and spinning test reports on cottons tested by him for the Institute of Plant Industry. The strains included in these tests are for the most part selected types bred and distributed by Departments of Agriculture, and are, therefore, to be regarded as representing the standards of quality obtainable by the growth of selected strains now available rather than those reached by the present crop. In making comparisons, the history of the material must be borne in mind. The Uplands in particular cannot be regarded as forming a representative sample of the species *G. hirsutum*, but only of those types in the species which it has been possible to acclimatise in India.

The material belongs to three species, *G. hirsutum*, *G. arboreum*, and *G. herbaceum*. All strains of *G. hirsutum* tested were of the typical form, while those of *G. herbaceum* were of its variety *frutescens*. Of *G. arboreum*, all strains, save Nandyal 14, were of variety *neglectum*. Nandyal 14 belongs to variety *typicum*. From the technological point of view, however, the distinction between var. *typicum* and var. *neglectum* is of no importance. The distinction of importance is that between the *G. arboreum* strains of Northern India (forma *bengalensis*), and those of Southern India (forma *indica*).

The term 'variety' is used in two senses, first in the botanical sense of varieties of a species, and secondly in the agricultural sense of agricultural varieties of a crop. To avoid any possible confusion in this paper, the terms 'botanical variety' and 'crop variety' will be used throughout.

Data for spinning value ('highest standard warp count' [Ahmad, 1933]), and the two most important hair characters (mean hair-length and mean hair-weight) for all tests available are given in Tables I-IV. Abbreviations in these and succeeding tables :—HSWC = highest standard warp count ; L = mean hair-length ; W = mean hair-weight per inch.

TABLE I

G. arboreum var. *neglectum* forma *bengalensis*

Highest standard warp counts, mean hair-length (1/100"), and mean hair-weights per inch (millionths oz./inch)

	Verum 262						Late Verum			Verum 434			Malvi 1			Malvi 5			Malvi 9		
	Nagpur			Akola																	
	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W
1924-25																					
1925-26																					
1926-27	24	84	185																		
1927-28	26	88	216	19	83	210															
1928-29	26	86	215	23	84	187															
1929-30	21	81	190 166	21	84	195 176															
1930-31	26	82	186	18	80	170	30	89	184												
1931-32	25	83	176	21	78	174	29	88	181				10	72	216	11	72	198	13·5	79	209
1932-33	23	82	180	25	82	163	31	86	184				12·5	78	188	12·5	77	185	14	82	203
													12·5	79	199	13	78	176	15·5	86	194
													15	77	169	16	76	162	17	80	183
1933-34	24	77	188	21	80	184	34	87	175	25	88	172									
1934-35	28	83	183	22	80	165	36	86	189	30	84	167									
Mean values																					
All data	24·8	83		21·3	81		32·0	87		27·5	86		12·5	77		13·1	76		15·0	82	
Before 1930			201·5			197·3			...			...			...			...			...
After 1929			179·8			172·0			182·6			169·6			193·0			180·3			197·3

TABLE I—*contd.*

	Aligarh 19			K 22			J N 1			Madhoganj C 402			Mollisoni			Sind N R		
	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W
1924-25	7	72	287	12	79	211	12	78	243									
1925-26	8	72	303	12	80	210	12	77	237				6	72	321			
1926-27	7	66	301	12	73	240	14	77	242				8	68	272			
1927-28	7	70	305	12	75	244	14	74	226				8	73	335			
1928-29	7	72	324	14	78	225	13	76	236				7	69	303			
1929-30	7	68	319 277	11	70	229 210	12	75	237 229				8	69	298 272	6	69	349
1930-31	7	66	301	12	76	196	12	76	218				8	69	287	6	62	333
1931-32	6	66	314	12	74	217				15	80	204	8	70	242	6	68	307
1932-33	6	67	290							14	79	195	10	74	274	6	62	299
1933-34	6	64	262							18	76	181	8	68	282	8	70	293
1934-35	6	66	271							22	81	164	9	72	268	9	70	263
Mean values																		
All data	6·7	68		12·1	76		12·7	76		17·3	79		8·0	70		6·8	67	
Before 1930			306·5			226·5			236·8			...			305·8			...
After 1929			285·8			207·7			223·5			186·0			270·8			307·3

TABLE II

G. arboreum forma *indica*

Highest standard warp counts, mean hair-length (1/100″), and hair-weight per inch (millionths oz./inch)

——	Umri Bani			Nandyal 14			Karunganni C 7		
	HSWC	L	W	HSWC	L	W	HSWC	L	W
1923-24				34	90	198			
1924-25	22	86	184	32	89	179	26	84	164
1925-26	24	83	184	32	88	176	26	83	173
1926-27	24	82	200	34	94	191	24	85	192
1927-28	24	82	192	31	88	196	24	85	183
1928-29	22	84	185	31	92	187	20	82	186
1929-30	27	81	172 152	35	92	190 169	23	84	196 181
1930-31	28	80	175	35	86	167	26	82	161
1931-32	27	79	172	30	85	187	21	82	181
1932-33	28	81	175	37	91	156	23	86	167
1933-34	29	83	166	37	89	163	25	82	164
1934-35	30	82	169	40	94	171	28	83	167
Mean values									
All data	25·9	82		34·0	90		24·2	83	
Before 1930			186·2			188·1			182·3
After 1929			168·2			168·8			170·2

TABLE III

G. herbaceum var. *frutescens*

Highest standard warp counts, mean hair-lengths (1/100"), and mean hair-weights per inch (millionths oz./inch)

	Jayawant			Surat 1027 A L F			Wagad 8 Dholleras			Wagad 4 Dholleras			Hagari 1			Hagari 25			Dharwar 1 Kumpta		
	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W
1923-24				30	100											24	90	210	34	88	202
1924-25				32	95	204							30	86	171	28	86	172	34	88	
1925-26				26	92	237	12	79	258	14	81	253	30	82	146	26	85	178	34	89	186
1926-27	38	88		32	98	200	14	80	264	16	85	257	27	82	209	26	76	177	34	89	204
1927-28	38	88	193	30	94	207	15	77	189	18	79	181				26	87	205	32	89	202
1928-29	38	96	207	32	96	204	15	80	239	16	84	216	24	84	207	30	90	188	34	87	182
1929-30	32	92	224 181	34	97	186 180	12	76	208 195				27	84	192 175	25	86	208 178	30	87	209 190
1930-31	37	96	175	29	94	201	12	78	257				36	91	166	36	90	195	30	86	164
1931-32	40	93	183	30	90	175	16	80	225				30	86	172	31	90	185			
1932-33	36	92	194	31	94	190	13	84	240				25	82	175	35	92	170			
1933-34	38	90	147	37	99	169	16	80	199				28	80	171						
1934-35	42	94	140	34	96	183	14	78	232				29	83	167						
Mean values																					
All data	37·7	92		31·4	95		13·9	79		16·0	82		28·6	84		28·7	87		32·8	88	
Before 1930			208·0			206·3			231·6			226·8			185·0			191·1			197·5
After 1929			170·0			183·0			224·7			...			171·0			182·0			177·0

TABLE IV

G. hirsutum

Highest standard warp counts, mean hair-lengths (1/100″), and mean hair-weights per inch (millionths oz. / inch)

	Gadag 1			P—A 4 F			P—A 285 F			P—A 289 F			Cwn. American C—A 9			Cambodia Co I 29 5		
	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W
1923-24	36	89	174				34	92	123							32	91	171
1924-25	20	81	154	22	80	177	34	92	152	36	102	125	28	89	163	30	86	147
1925-26	30	82	150	22	82	174	28	93	155	30	100	125	28	87	147	32	91	156
1926-27	38	81	179	24	78	134	34	82	104	38	97	98	34	87	182	38	92	155
1927-28	38	86	167	22	79	186	34	89	133	40	94	142	30	86	176	34	93	164
	24	81	182															
	32	83	164															
1928-29	26	82	162	16	76	197	34	88	125	38	96	122	40	89	166	32	93	170
1929-30	32	84	166 148	20	82	179 155	42	92	158	42	100	147 142	34	87	174 165	34	89	175 146
1930-31	35	88	153	22	77	198				44	96	142	37	86	154	29	87	156
1931-32	29	80	154	20	72	161				39	90	122	36	84	157			
1932-33	30	81	134	25	78	143				44	95	114	39	84	134			
1933-34	30	81	153	24	73	140				45	94	119						
1934-35	33	79	147	27	82	142				45	94	120						
Mean values																		
All data	30·9	83		22·2	78		34·3	90		40·1	96		34·0	87		32·6	90	
Before 1930			166·4			174·5			135·7			126·5			168·0			162·6
After 1929			148·2			156·5			...			126·5			152·5			151·0

TABLE IV—*contd.*

	Cambodia Co II 440			Texas			Sind Sudhar			Dhar Cambodia (I P I)			Indore 1 (I P I)			Indore 25 (I P I)		
	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W	HSWC	L	W
1923-24				24	85	213												
1924-25	29	92	172															
1925-26	25	92		30	86	206												
1926-27	37	94	168	20	83	234												
1927-28	33	88	141															
1928-29	26	92	148															
1929-30	28	90	172 136															
1930-31	29	92	133				42	98	146									
1931-32	27	90	145				42	92	126	21	89	152						
1932-33	24	92	123				50	90	129	24	85	140	22	87	129	21	76	144
										22	81	149	21	88	151	12·5	72	143
										30	83	165	14	81	114			
1933-34	26	88	122				50	102	131									
1934-35	30	92	132				43	97	127									
Mean values																		
All data	28·6	91		24·7	85		45·4	96		24·3	85		19·0	85		16·8	74	
Before 1930			160·2			217·7			...			...			...			...
After 1929			131·8			...			131·8			151·5			131·3			143·5

Mean hair-length is given in units of 1/100″, and mean hair-weight in millionths of an ounce per inch. Up to 1929-30, one cm. lengths were cut from near the middle of groups of parallel hairs, weighed and counted. After that, groups of whole hairs were weighed, and the weight corrected for mean hair-length. In 1929-30 both methods were used [Ahmad, 1933].

The data in Tables I-IV were studied by the method of the analysis of variance and covariance. First an analysis was made of the whole data, the variances and covariances being partitioned into—

(1) Differences between species.

(2) Differences between northern and southern forms of *G. arboreum.*

(3) Differences between crop varieties of the same species and form.

(4) Differences within crop varieties in different seasons and localities.

Secondly each species and form was taken separately, and the variances and covariances partitioned into—

(1) Differences between crop varieties.

(2) Differences within crop varieties in different seasons and localities.

In the southern *arboreum*, by omitting the records for Nandyal 14 in 1923-24, it becomes possible to separate the effect of season from the residual, and this has been done.

Summaries of the analyses are given in Tables V-IX.

TABLE V

Spinning value and mean hair-length

Analyses of variance and covariance and correlation coefficients

Statistic / Due to differences between	Degrees of freedom †	Mean square: Spinning value	Mean square: Mean hair-length	Mean product	*r*
All species together					
Species	2	4072·5	2368·0	+3024·4	+0·981
G. arboreum N. v. S.	1	4265·4	1971·0	+2900·0	
Crop varieties	30	441·3	285·1	+306·7	+0·864**
Residual	233	9·9	8·2	+2·1	+0·230**
Total	266	105·1	64·5	+70·0	+0·850**
Species and forms separately					
G. arboreum (northern)					
Crop varieties	11	425·6	286·1	+331·6	+0·950**
Residual	70	3·9	7·4	+1·6	+0·278*
Total	81	61·2	45·3	+46·3	+0·880**
G. arboreum (southern)					
Crop varieties	2	302·2	187·0	+224·8	+0·946
Season	10	16·4	7·4	+0·8	+0·069
Residual	20	3·4	3·8	+0·4	+0·119
Total	32	26·1	16·4	+14·6	+0·704**
G. herbaceum					
Crop varieties	6	622·1	311·0	+356·2	+0·810
Residual	56	8·2	9·2	+4·1	+0·471**
Total	62	67·7	38·4	+38·2	+0·749**
G. hirsutum					
Crop varieties	11	380·5	285·8	+267·5	+0·811**
Residual	76	17·7	9·5	+1·7	+0·133
Total	87	63·7	44·5	+35·3	+0·664**

† Degrees of freedom for correlation coefficients are one less than those given in this column.

* *P*=0·05 ** *P*=0·01

Table VI

Analyses of variance of mean hair-weight (before 1930) and analyses of co-variance, and correlation coefficients of mean hair-weight (before 1930) with spinning value and mean hair-length

Statistic / Due to differences between	Degrees of freedom†	Mean square	Mean products		r	
			With spinning value	With mean hair-length	With spinning value	With mean hair-length
All species together						
Species . . .	2	54708	—9845	—62·57	—0·967*	—0·915
G. arboreum N. v. S. .	1	50440	—10805	—78·39		
Crop varieties . .	19	4677	—702	—5·99	—0·675**	—0·644**
Residual . .	111	286	—7	+0·11	—0·138	+0·244**
Total .	133	2109	—336	—2·30	—0·779**	—0·671**
Species an forms separately						
G. arboreum (northern)						
Crop varieties . .	4	14176	—1720	—16·37	—0·893*	—0·936*
Residual . .	25	219	+1	+0·06	+0·035	+0·155
Total .	29	2144	—236	—2·20	—0·828**	—0·800**
G. arboreum (southern)						
Crop varieties . .	2	32	+39	+0·27	+0·561	+0·471
Seasons . . .	5	155	—1	+0·06	—0·023	+0·321
Residual . .	10	67	—11	+0·02	—0·786**	+0·107
Total .	17	89	—2	+0·06	—0·044	+0·165
G. herbaceum						
Crop varieties . .	6	1525	—484	—1·73	—0·692	—0·339
Residual . .	29	513	—31	+0·18	—0·614**	+0·271
Total .	35	686	—108	—0·15	—0·539**	—0·095
G. hirsutum						
Crop varieties . .	7	3271	—531	—5·58	—0·751**	—0·686
Residual . .	41	239	+4	+0·12	+0·056	+0·287
Total .	48	681	—74	—0·71	—0·451**	—0·457**

† Degrees of freedom for correlation coefficients are one less than those given in this column.

* $P=0·05$ ** $P=0·01$

Table VII

Analyses of variance of mean hair-weight (after 1929) and analyses of covariance, and correlation coefficients of mean hair-weight (after 1929) with spinning value and mean hair-length

Statistic / Due to differences between	Degrees of freedom†	Mean square	Mean products		r	
			With spinning value	With mean hair-length	With spinning value	With mean hair-length
All species together						
Species	2	58384	—10859	—72·47	—0·924	—0·824
G. arboreum N. v. S.	1	32884	—9201	—55·77		
Crop varieties	27	5792	—903	—8·08	—0·631**	—0·732**
Residual	119	216	—10	—0·01	—0·236*	—0·035
Total	149	2226	—379	—2·82	—0·731**	—0·708**
Species and forms separately						
G. arboreum (northern)						
Crop varieties	11	12623	—1624	—15·45	—0·789**	—0·896**
Residual	46	264	—11	—0·10	—0·306	—0·236
Total	57	2649	—322	—3·06	—0·755**	—0·837**
G. arboreum (southern)						
Varieties	2	6	—18	+0·02	—0·508	+0·056
Seasons	5	94	—24	—0·19	—0·651	—0·627
Residual	10	82	—6	0·00	—0·481	+0·018
Total	17	76	—13	+0·05	—0·273	—0·139
G. herbaceum						
Crop varieties	5	2487	—895	—4·54	—0·917**	—0·658
Residual	24	262	—18	+0·02	—0·325	+0·036
Total	29	645	—169	—0·77	—0·765**	—0·474**
G. hirsutum						
Crop varieties	9	597	—221	—2·85	—0·457	—0·803**
Residual	34	167	—1	+0·09	—0·033	+0·213
Total	43	257	—47	—0·52	—0·312**	—0·446**

† Degrees of freedom for correlation coefficients are one less than those given in this column.

* *P*=0·05 ** *P*=0·01

TABLE VIII

Partial correlations between (1) spinning value, (2) hair-length, and (3) hair-weight (before 1930)

Due to differences between / Statistic	Degrees of freedom†	Partial correlations r 12·3	r 13·2
All species together			
Main groups	1	+1·000**	—1·000**
Crop varieties	17	+0·766**	—0·308
Residual	109	+0·257**	—0·203*
Total .	131	+0·636**	—0·532**
Species and forms separately			
G. arboreum (northern)			
Crop varieties	2	+1·000**	+1·000**
Residual	23	+0·361	—0·023
Total .	27	+0·781**	—0·389*
G. arboreum (southern)			
Crop varieties	0	..	..
Season	3	—0·051	—0·005
Residual	8	+0·376	—0·816**
Total .	15	+0·845**	—0·323
G. herbaceum			
Crop varieties	4	+0·860	—0·767
Residual	27	+0·494**	—0·714**
Total .	33	+0·815**	—0·694**
G. hirsutum			
Crop varieties	5	+0·681	—0·441
Residual	39	+0·240	—0·016
Total .	46	+0·555**	—0·230

† Degrees of freedom for correlation coefficients are one less than those given in this column.

* $P=0\cdot05$ ** $P=0\cdot01$

TABLE IX

Partial correlations between (1) spinning value, (2) hair-length, and (3) hair-weight (after 1929)

Due to differences between / Statistic	Degrees of freedom†	Partial correlations	
		r 12·3	*r* 13·2
		All species together	
Main groups	1	+0·963	—0·906
Crop varieties	25	+0·761**	+0·003
Residual	117	+0·389**	—0·241**
Total	147	+0·730*	—0·330**
		Species and forms separately	
		G. arboreum (northern)	
Crop varieties	9	+0·845**	+0·322
Residual	44	+0·186	—0·264
Total	55	+0·704**	—0·059
		G. arboreum (southern)	
Crop varieties	0	..	..
Seasons	3	+0·385	—0·419
Residual	8	+0·465	—0·532
Total	15	+0·764**	—0·262
		G. herbaceum	
Crop varieties	3	+0·887	—0·927
Residual	22	+0·713**	—0·466*
Total	27	+0·836**	—0·765*
		G. hirsutum	
Crop varieties	7	+0·790*	+0·469
Residual	32	+0·288	—0·097
Total	41	+0·676**	+0·009

† Degrees of freedom for correlation coefficients are one less than those given in this column.

* *P*=0·05 ** *P*=0·01

Comparison of variances.—Considering first the main analysis (all species together), the mean squares for all characters due to the differences between northern and southern crop varieties of *G. arboreum* are practically equal to those due to differences between species. Differences between crop varieties contribute mean squares only about one-tenth as great as those due to differences between the main groups, while the contribution of the residuals (environmental effects) is only from three to five per cent of that due to crop varieties. Below are given the means of the variety means for each main group :—

Main group	HSWC	Lint length	Hair-weight	
			Earlier method	Later method
G. arboreum (northern) . .	15·6	77·2	255·0	215·3
G. arboreum (southern) . .	28·0	85·0	185·5	169·1
G. herbaceum . . .	27·0	86·7	206·6	184·6
G. hirsutum	29·4	87·5	164·0	142·5

In hair-length and spinning value, practically the whole of the differences are those between the northern *arboreums* and the remaining groups. In hair-weight also, the difference between the coarse northern *arboreums* and the rest is considerably the greatest, though in this character *G. hirsutum* is considerably finer than any other group.

The three Verum strains included in the northern *arboreums* are Central Provinces selections, and from the history of cotton in that area it must be regarded as likely that they may owe their superior hair and spinning properties to hybridisation with southern *arboreums*. If they are omitted, the contrast between the northern *arboreums* and all other types is even greater.

Taking species and forms separately, in spinning value and mean hair-length the amount of variation between crop varieties is least in the southern *arboreums* but the differences between groups are not great.

In hair-weight, the mean squares for crop varieties obtained by the two methods of estimation agree satisfactorily in the northern and southern *arboreum* groups. In *G. herbaceum*, the crop variety mean square is considerably less in the data collected by the earlier method. This difference is due to the inclusion of different varieties in different years. In *G. herbaceum* the Wagads have much higher hair-weights than other types, and two

Wagad strains were included before 1930, and only one subsequently. Omitting the Wagad data, the analyses of variance of hair-weight in the *herbaceums* become as follows :—

	Before 1930		After 1929	
	Degrees of freedom	Mean square	Degrees of freedom	Mean square
Between crop varieties . .	4	461	4	201
Season and localities . .	22	313	19	195

The variances do not differ greatly, and in both sets of data they are about the same as the environmental variances, showing that apart from the Wagads, the Indian *herbaceums* are very homogeneous in hair-weight. In *G. hirsutum* the variance due to crop varieties is much greater in the earlier data than in the later. The change in the method of measuring hair-weight appears to have resulted in a real reduction in the differences between crop varieties, the hair-weights of the heaviest having been reduced while those of the lightest remained unchanged. The inclusion in the earlier data of Texas, with a much higher hair-weight than the Indian *hirsutums*, has further increased the difference between the mean squares. In both sets of data there was very little variation between southern *arboreum* crop varieties. Examination of a larger range of southern *arboreum* types would be of great interest. The low variances obtained for all characters from the present data may be due to the choice of only three similar crop varieties for study, and a more extensive study may reveal greater variation. The importance to plant breeders of knowledge of the range of variation in quality in the finer sections of *G. arboreum* requires no emphasis.

The residual effects (primarily environment) differ very considerably in the different groups. In spinning value, the mean square due to residual is significantly less in the northern *arboreums*, and in the Uplands (*G. hirsutum*) significantly greater than in the other two groups. In mean hair-length, on the other hand, the seasons *plus* residual mean square for the southern *arboreums* is less than for all other groups and significantly less than for *G. herbaceum* and *G. hirsutum*. In hair-weight, season *plus* residual effects caused significantly less variation in the southern *arboreums* than in any other group, in both sets of data. In the earlier set of observations, but not in the later, *G. herbaceum* was significantly more variable than the other groups. In the southern *arboreums*, for which seasonal effects could be estimated separately, season had a significantly greater effect on spinning value than had the residual. In hair-length and hair-weight seasonal and residual effects were not significantly different.

These differences in behaviour are remarkable, and of great practical interest. The effect of environment on hair properties was very much less in the southern *arboreums* than in any other group. The other three groups responded similarly to environmental influences, except that in the earlier data *G. herbaceum* was more variable in hair-weight than the rest. In spinning value, the lowest spinning group (northern *arboreums*) was, as might have been expected, least affected by environmental influences, while the exotic *G. hirsutum*, which is known to be on the whole less adapted to Indian conditions than the indigenous species, fluctuated much more than they did.

Correlations due to main groups.—In studying the associations between hair properties and spinning value between main groups, the correlation coefficients are of little value, since there are only four pairs of observations for their determination. The associations are, however, of a very high order (r approaching unity) positive for hair-length and spinning value, and negative for hair-weight and spinning value, and hair-length and hair-weight. Inspection of the mean products again shows that the differences between northern and southern *arboreums* are of the same kind and magnitude as between species.

Correlations due to crop varieties.—Between hair-length and spinning value there was a high positive correlation ($r=+0\cdot9$, P very small) taking all data together, and the correlations in the four main groups were all about the same ($r=+0\cdot95$, $+0\cdot94$, $+0\cdot81$ and $+0\cdot81$ respectively). The corresponding partial correlations with hair-weight constant were in no case significantly different from the total correlations. Between hair-weight and spinning value the correlation was strong and negative ($r=-0\cdot675$ in the earlier data and $r=-0\cdot631$ in the later, P very small). The correlations in the four main groups agreed satisfactorily with those in the totals except for the earlier data on the southern *arboreums* ($r=+0\cdot777$). As there was only one degree of freedom for the estimation of the correlation, this figure is, of course, of very little value. The corresponding partial correlations with hair-length constant differed from the total correlations in several important respects. Taking all crop varieties together, in the earlier data the correlation was reduced from $-0\cdot675$ to $-0\cdot308$ and in the later data from $-0\cdot631$ to $+0\cdot003$. The change is significant in the later data only. No comparison is possible in the southern *arboreums*, the number of crop varieties being inadequate. In the *herbaceums* the partial correlations were practically the same as the total. In the northern *arboreums* the partial correlations were positive, instead of negative as in the total correlations, and in the Uplands the partial correlation was much less than the total correlation (though still negative) in the earlier data, and was positive in the later data. As the number of crop varieties was small in each case, the changes were insignificant but it appears likely that, in some cases at least, differences between crop varieties in hair-weight affect spinning value only in so far as they are associated with differences in hair-length.

Correlations due to environmental effects.—The correlations due to environmental differences are surprisingly small. Between hair-length and spinning value there was a small but significant positive correlation ($r=+0\cdot192$). The value of the correlation varied considerably in different groups, but the differences were not significant. The partial correlations with hair-weight constant were in all cases somewhat, but not significantly, higher than the total correlations. Between hair-weight and spinning value there were small negative correlations ($r=-0\cdot138$ and $r=-0\cdot236$) which cannot be regarded as significant*. The correlations in the main groups did not differ significantly from the total correlation. Partial correlations were very little different from the corresponding total correlations. Between hair-length and hair-weight the correlation was insignificant except in the main analysis of the earlier data ($r=+0\cdot244$).

Pierce and Lord [1934] concluded that measurement of the diameters of hairs swollen in eighteen per cent caustic soda will give an excellent estimate of the intrinsic fineness of a cotton. In Table X are given the relevant data from Pierce and Lord's Table V, re-arranged according to species and form.

TABLE X

Hair-weights per cm., standard hair-weights, and swollen hair diameters of cottons of different species (From Pierce and Lord, 1934)

Species	Type	Hair-weight per cm.	Standard hair-weight	Swollen hair diameter
G. barbadense (Egyptian and Sea Island)	Nahda	155	152	21·78
	Sakha 7	125	122	20·31
	Peruvian Pima	160	170	22·56
	Maarad	141	135	21·13
	Sakel Domains	133	132	20·91
	Uppers	188	184	22·62
	Sakel	135	135	21·26
	V 135	171	168	22·28
	Sakha 7	165	161	21·98
	Sakha 7	151	145	21·15
G. barbadense (South American types)	Ecuador	242	263	27·08
	Iquitos	265	267	27·68
G. hirsutum	Texas	226	230	25·11
	Boweds	230	242	25·17
	Sudan American	159	170	22·20
	Nigerian	173	180	22·50
	Texas	207	218	24·46
G. arboreum (Northern Indian)	*G. arboreum*	356	321	30·94
	Oomras improved	274	271	27·58
	Khandeish	319	298	30·26

---

* This is in agreement with Turner and Underwood's [1934] findings.

TABLE X—*contd.*

Species	Type	Hair-weight per cm.	Standard hair-weight	Swollen hair diameter
G. arboreum (Southern Indian)	Madras Northerns	213	217	24·59
	Karunganni	223	222	25·69
	Tinnivelly	232	230	25·25
G. arboreum (Burmese and Chinese)	Chinese	337	328	32·16
	Rangoon	287	324	30·84
	Chinese	412	386	35·39
G. herbaceum var. *frutescens*	Broach	264	268	28·54
	Surat	303	290	29·75
	Hagari	238	234	25·26

Species not known : F. B.
California
Russian

Analyses of variance and covariance were carried out for hair-weight per cm., standard hair-weight and swollen hair diameter. The data are not altogether comparable with those given in earlier tables. They cover a much wider range of material, and the differences between types of the same species and main group are, on the average, greater than the differences between crop varieties in the Technological Laboratory material. Also, in at least one case (Sakha 7) the same crop variety appears more than once. No attempt has been made to determine the magnitude of environmental effects by extracting the sums of squares due to differences between samples of the same crop variety because it is not known whether the two Texas samples and the two Chinese samples represent paired observations on the same crop varieties, or observations on pairs of crop varieties from the same countries, and in all other cases, each type appears only once. Below are summarised the analyses of variance :

Due to	Degrees of freedom	Mean squares		
		Hair-weight per inch	Standard hair-weight	Swollen hair diameter
Between main groups	6	21962	20678	66·48
Between species	3	30024	26397	85·10
E. & S. I. v. South American *G. barbadense*	1	17035	21889	55·72
Between forms of *G. arboreum*	2	12331	11495	43·92
Within groups	22	968	586	1·93
Total	28	5467	4892	15·76

In all three characters, differences between species gave the largest mean square. *G. barbadense* has not appeared in any of the data previously considered. The differences between the coarse South American group and the fine Egyptian Sea Island group were second in magnitude only to those between species. Three forms of *G. arboreum* appear, *viz.*, the northern and southern Indian forms already considered, and the Burmo-Chinese group which does not occur in any of the Technological Laboratory material. Differences between them gave mean squares rather less than half those due to differences between species. Differences between types of the same main group gave mean squares about one-twelfth to one-twentieth of the magnitude of those between forms of *G. arboreum*, so that the conclusion drawn from the Technological Laboratory data, that differences between forms of the same species are similar in magnitude to those between species, and much greater than those between crop varieties of the same form, still holds.

The correlations between the two estimates of hair-weight and swollen hair diameter were as follows :—

Due to differences between	Degrees of freedom	Correlation between swollen hair diameter and			
		Hair weight per inch		Standard hair-weight	
		r	z	r	z
Main groups . . .	5	+0·994	2·91	+0·995	3·00
Types within main groups .	21	+0·937	1·71	+0·934	1·69

The association between hair weight and swollen hair diameter was practically complete. The value of z is given for each value of r. The standard error of the difference between z for the main groups and z for types within groups is 0·621 and the differences are 1·20 for hair-weight per inch and 1·31 for standard hair-weight. It is probable, therefore, that the difference between the correlations within and between groups is real.

Data for highest standard warp count, hair-weight per inch and swollen hair diameter are available from twenty-seven samples of Malvi cottons (Table XI). Hair-weights and spinning values were determined at the Technological Laboratory, Bombay, and the swollen hair diameters were determined at Indore from samples unravelled from hanks of yarn from the spinning tests by the following method :—

From the yarns received from the Technological Laboratory ten samples were taken by removing one-inch lengths of yarn at ten-foot intervals. The samples were carefully unwound and the hairs irrigated with eighteen per cent caustic soda solution. The diameter was measured on ten hairs per sample, giving 100 measurements per strain.

TABLE XI

Highest standard warp counts, hair-weights per inch, and swollen hair diameters of Malvi samples (G. arboreum *var.* neglectum *forma* bengalensis)

Strain	Sample	HSWC	Hair-weight per inch	Swollen hair diameter (μ)
Dhar Mass Malvi 1	1935-36	11	234	24·4
2	1935-36	21	185	23·6
3	1935-36	13	231	26·4
4	1935-36	24	155	20·4
5	1935-36	22	186	24·4
6	1935-36	21	185	24·8
7	1935-36	11	206	24·6
Malvi 9 bulk	1935-36	16	207	26·0
9-13	1935-36	20	195	23·6
9-15	1935-36	15	182	24·5
9-17	1935-36	22	199	24·2
9-19	1935-36	13	227	25·0
9-20	1935-36	21	187	24·4
Malvi 1	1931-32	10	216	28·5
	1932-33 M*	12½	188	27·2
	1932-33 P*	12½	199	30·3
	1932-33 N*	15	169	29·0
Malvi 3	1931-32	13	200	27·2
Malvi 5	1931-32	11	198	28·0
	1932-33 M	12½	185	28·0
	1932-33 P	13	176	26·0
	1932-33 N	16	162	28·9
Malvi 8	1931-32	7	244	28·2
Malvi 9	1931-32	13½	209	30·3
	1932-33 M	14	203	29·2
	1932-33 P	15½	194	30·9
	1932-33 N	17	183	28·3

*M = Medium land, Indore, C. I.
P = Poor land, Indore, C. I.
N = Medium land, Narsingarh, C. I.

The correlation between hair-weight and swollen hair diameter was small and insignificant: $r=+0\cdot159$, $P=0\cdot5$. The correlation between spinning value and swollen hair diameter, however, was large and significant ($r=-0\cdot580$, $P=0\cdot01$), and was about equal to the correlation between hair-weight and spinning value, which was $r=-0\cdot597$, $P=0\cdot01$. Thirteen of the samples consisting of sub-strains of Dhar Mass Malvi and Malvi 9 were grown in 1935-36. The mean values of the two strains were closely similar, so that differences between strains contribute little to the correlations. In this closely related material grown in the same season, the correlation between hair-weight and swollen hair diameter was high and significant: $r=+0{\cdot}720$, $P=0{\cdot}01$, the correlation between hair-weight and spinning value was $r=-0{\cdot}800$, $P=0{\cdot}01$, and that between spinning value and swollen hair diameter was the same as in the whole data: $r=-0{\cdot}576$, $P=0{\cdot}05$.

The rest of the data is from a group of Malvi strains (including Malvi 9) tested in different years and under different conditions, and the reduction in the hair-weight—swollen hair diameter correlation from $+0{\cdot}720$ to $+0{\cdot}159$ may perhaps be ascribed to the introduction of environmental factors affecting primarily the degree of secondary thickening of the hair, and therefore influencing hair-weight and not swollen hair diameter. The swollen hair diameter method seems promising as an aid to the plant breeder, but further work is required to account for the difference between Pierce and Lord's [1934] findings and those of the present study.

III. DISCUSSION

The analysis of the associations between characters reveals the highly heterogeneous nature of the components of the correlations commonly used in technological literature to express the relationship between hair characters and spinning value. This was noted also by Turner and Underwood [1934], though they did not separate out specific differences in their analysis, and they concluded that environmental and varietal differences probably affect spinning value in different ways. The present analysis supports this conclusion. Turner and Underwood discussed the relative importance of hair-length and hair-weight in three sets of data, Indian, Empire and Egyptian. From a study of partial correlations they concluded that " Only for the Indian cottons does the fibre-length show any superiority over hair-weight as a measure of spinning value ". The partition of the Indian data into botanical groups necessitates a fresh examination of the problem (Tables VIII and IX). Considering correlations due to differences between crop varieties only, in the *herbaceum* group the partial correlations of hair-length with spinning value and hair-weight with spinning value were almost equal and of opposite sign. In the *hirsutum* group, contrary to Turner and Underwood's findings with Empire cottons (most of which were *hirsutums*), the hair-length-spinning-value correlation was greater than that for hair-weight and spinning value, and in addition the two estimates of the hair-weight-spinning-value correlation were of opposite sign. The change was due to the inclusion in the later data of two Indore strains of low spinning value and low hair-weight. Correction for immaturity would probably reduce the inconsistency considerably, as the Indore types were grown under very unfavourable conditions [Gulati and Ahmad, 1935], but the fact remains that among *hirsutum* samples in India, hair-length was a much better estimate of spinning value than hair-weight. In the northern *arboreums* also, hair-length was superior to hair-weight as an estimate of spinning value, but in this case partial correlation between hair-weight and spinning value was positive (but not significant).

Turner and Underwood's [1934] plea for the co-operation of plant breeders in the collection of material specially selected for the elucidation of these inconsistencies may be heartily endorsed, but it is clear that in deciding on the range of samples to be examined, full allowance should be made for differences in the behaviour of different botanical groups. It may further be suggested that the analysis of the available data from Empire and Egyptian cottons would be simplified if they were grouped according to their botanical relationships rather than by their countries of origin.

Comparison of Pierce and Lord's [1934] data for the relation between swollen hair diameter and hair-weight, with those available for Malvi cottons shows a much lower correlation in the latter than in the former. Environmental effects appear to have lowered the correlation between swollen hair diameter and hair-weight considerably, but not to have affected that between swollen hair diameter and spinning value to any great extent.

This analysis of technological data has been undertaken primarily as an attempt to assess the value of hair property determinations to the plant breeder, and from that point of view the correlations of interest are those due to differences between varieties. It is, therefore, very satisfactory that the environmental variances are in all cases very small compared with the crop variety variances. Environmental correlations also are usually small, so that in general the plant breeder is safe in assuming that much the greater part of the differences, he observes, is of genetic origin.

For plant breeding purposes, the labour involved in the determination of hair-weight is prohibitive. The demonstration by Pierce and Lord [1934] of the close relationship between hair-weight and swollen hair diameter opened up a new method of determining fineness, and the data given above for hair-weight, spinning value and swollen hair diameter in closely related Malvi strains tends to confirm the value of the method for estimating fineness in the kind of material with which the plant breeder works, though further work is necessary. The estimation of fineness in plant breeding work is of greater importance than might be expected from an inspection of the correlation coefficients given above, on account of the effect of changes in hair-weight on ginning percentage. The development of a method whereby selection for high ginning percentage could be carried on without risk of developing a coarse lint is one of the most pressing problems in cotton breeding, and the determination of swollen hair diameter provides a possible solution.

Two important facts stand out from the botanical analysis. The first is that the inferior cotton of India belongs almost exclusively to one of the four main groups of crop varieties, the northern *arboreums*. The second is that, in spite of the reputation for high quality enjoyed by the acclimatised Upland cottons, they are not in fact appreciably superior in spinning value to either the southern *arboreums* or the *herbaceums*. This is disappointing when the amount of work expended in recent times on their improvement is considered. They are undoubtedly superior to all other Indian groups in fineness, but this superiority is not reflected in their spinning value as judged by the highest standard warp count. From the point of view of their effect on the quality of the Indian crop, the great achievement with Upland cottons has been the development of the production of staple cotton in the canal colonies of the Punjab and Sind. The present analysis of the position leads to the conclusion that the same result could equally well have been attained with the finer groups of the indigenous cottons, had adequate knowledge been available of their distribution and relationships. The technological data, therefore, lend strong support to the botanical considerations which led to the initiation by the Indian Central Cotton Committee of a scheme for the collection, maintenance and breeding in the Bengals tract of strains of *G. arboreum* var. *naglectum* with superior hair properties, in order to provide an adequate range of high quality material for plant breeders working on coarse-stapled cottons in tracts unsuitable for the introduction of Upland types.

Omitting the northern *arboreums*, the standard Indian cottons of the other three main groups give an average highest standard warp count of 28's—a very satisfactory figure. It has been shown elsewhere [Hutchinson, 1937] that the invasion by the northern *arboreums* of the greater part of the area they now cover is an event of the past century, and the demonstration of the great difference in quality between them and all other groups is sufficient to show that the present position of India as a producer of a great bulk of coarse-stapled cotton is of recent origin. It must be ascribed to the economic forces at work during the development of the modern ginning and spinning industry, whereby coarse, high ginning types were favoured at the expense of the medium staple *G. arboreum* forma *indica*. The demonstration of the superiority of the southern *arboreums* should encourage the cotton breeders of northern and Central India to study them intensively. Two promising lines of approach are open. One is the search for plants of the southern type in the mixtures grown in areas recently invaded by the northern form. This has already yielded results of great value in the Central Provinces, Khandesh and neighbouring areas in Central India, and the recent discovery of similar types in Rajputana [Hutchinson and Ghose, 1937, 1] has made possible its extension to the Bengals tracts. The other is the study of crosses between the northern and southern forms. Strains derived from a cross between C 520 and Bani now under study at Indore hold out considerable promise as medium staple, high ginning types suitable for parts of the Bengals tracts.

So large a proportion of the Indian cotton crop is derived from one or other of the forms of *G. arboreum* that the range of variability of the finer forms in important commercial characters deserves the special attention of cotton research workers. The southern *arboreums* are obviously the most important group for study, and the inclusion of more of them in the standard Indian cottons would provide a welcome addition to knowledge of their variability in characters of technological importance. Data obtained from preliminary collections of types of the Burmese group indicate the existence, in the Indo-Chinese peninsular also of types of high commercial value.

The likelihood that the high quality of the Central Provinces Verum strains results from the occurrence of southern *arboreums* in their ancestry has already been mentioned. Strains of Malvi cotton have also been selected which spin over 20's, and it is possible that the ancestry of the medium staple Malvi crop includes a fair proportion of moderately fine types similar to those recently discovered in Rajputana. The possibilities of improvement in quality by local selection in the true Bengals tracts such as the United Provinces and the Punjab appear to be very small, and hybridisation with introduced southern *arboreums* is probably the most promising line for improvement in quality in those areas.

The relatively slight influence of environment on quality in the southern *arboreums* is interesting and, if confirmed on further material, may be of value in the breeding of strains of uniform quality over a wide range of seasonal fluctuations.

If the acquisition of adequate information concerning the range of variability, and the maintenance of a wide range of the best available types, is of fundamental importance for the improvement of the coarse northern *arboreums*, it is no less important for the maintenance and improvement of the *G. herbaceum* var. *frutescens* cottons of western India. It has been shown elsewhere [Hutchinson and Ghose, 1937, 2 and Hutchinson, 1937] that the Wagad cottons of Gujarat are botanically allied to the *G. herbaceum* var. *typicum* cottons of Iran and Central Asia. Technologically, they form a group much inferior in quality to the rest of the Indian *herbaceums*. Like the southern *arboreums*, they have suffered seriously from the invasion of the coarse northern *arboreums* (the Mattheo of Kathiawar). Their improvement in quality, and the recovery of the ground recently lost, depends upon knowledge of the range of variability within the type, and upon an understanding of the constitution and variability of the early-fruiting *herbaceum* types of Iran and neighbouring regions, sufficient to enable the plant breeder to exploit the available material to the full. In this connection it is interesting to note that the Russian workers are beginning to exploit the finer components of *G. herbaceum* indigenous in their own and neighbouring cotton-growing tracts, instead of concentrating exclusively on acclimatised exotic species [Bordakov and Ivanova, 1935 ; Konstaninov, 1936].

IV. SUMMARY

The technological data available for standard Indian cottons have been analysed according to botanical relationships. It is shown that the different botanical types differ greatly in mean spinning values and hair properties. The greatest differences are between the short, coarse, low-spinning *G. arboreum* var. *neglectum* forma *bengalensis* of northern India, and the other botanical groups. The other groups differ in hair-weight, the Uplands being the finest and the *herbaceums* the coarsest, but have very similar hair-lengths and spinning values.

The data show that the reputation of India as a producer of coarse-stapled cotton depends almost entirely on one of the four botanical types now cultivated. As it has already been shown [Hutchinson and Ghose, 1937, 1 ; Hutchinson, 1937] that the coarse northern *arboreum* type has invaded most of the areas in which it now predominates in quite recent times, it is concluded that India has become a producer of coarse cottons by force of economic circumstances, and not on account of any inferiority in her indigenous cottons.

It is shown that the introduced Upland cottons differ very little from the superior indigenous types in spinning value. If adequate botanical and technological surveys are made of the range of variability available in the indigenous species, improvement in quality is likely to be attained as rapidly with them as with exotic types.

The relative importance of differences in crop variety, and in environment is examined, and it is shown that differences in hair properties and spinning value due to differences in environment are very small compared with those due to crop variety. Also, correlations between hair properties and spinning value are very much higher when calculated from differences in crop variety than from differences in environment. This is fortunate from the plant breeding point of view, since it minimises the errors, which will arise from the estimation of strain differences in spinning value from hair characters measured on small quantities of cotton from progeny rows.

The swollen hair diameter method of determining fineness is discussed, and it is concluded that, if it is satisfactory after more extended trial, it will put the quantitative study of fineness within the reach of the plant breeder. Its importance is emphasised in enabling the plant breeder to select for high ginning percentage without the risk of loss of quality.

V. ACKNOWLEDGMENTS

The extent of our indebtedness to the Director of the Indian Central Cotton Committee's Technological Laboratory, Bombay, will be obvious from an inspection of the tables, but we take this opportunity of acknowledging our gratitude for the use of data both published and supplied to

the Institute of Plant Industry, and for the assistance and criticism afforded in conversation and correspondence.

We are also indebted to Mr. V. G. Panse for considerable assistance in the planning of the statistical part of the investigation.

REFERENCES

Ahmad, N. (1932). *I. C. C. C. Tech. Lab. Bull.* (*Ser. A*) **21**.

——— (1933). *I. C. C. C. Tech. Lab. Bull.* (*Ser. A*) **25**.

Bordakov, L. P. and Ivanova, M. M. (1935). Abstract in *Pl. Br. Abst.* **7**, 68.

Editorial (1932). *E. C. G. Review* **9**, 269.

Gulati, A. N. and Ahmad, N. (1935). *I. C. C. C. Tech. Lab. Bull.* (*Ser. B*) **20**.

Hutchinson, J. B. (1937). *I. C. C. C. Conf. of Sci. Workers on Cotton.*

Hutchinson, J. B. and Ghose, R. L. M. (1937, 1). *Ind. J. Agric. Sci.* **7**, 1.

——— (1937, 2). *Ind. J. Agric. Sci.* **7**, 233.

Konstantinov, N. M. (1936). *Sojuzuikhi* (*Tashkent*).

Pierce, F. T. and Lord, E. (1934). *Rep. and Summ. of Proc., 2nd Conf., on Cotton Gr. Prob.*, p. 223 ; E. C. G. C.

Turner, A. J. and Venkataraman, V. (1933). *I. C. C. C. Tech. Lab. Bull.* (*Ser. B*) **17**.

Turner, A. J. and Underwood, C. (1934). *Rep. and Summ. of Proc., 2nd Conf., Cotton Gr. Prob.*, p. 280 ; E. C. G. C.

ALTERNARIA BLIGHT OF CUMIN

BY

B. N. UPPAL

Plant Pathologist to the Bombay Government

M. K. PATEL

Assistant Professor of Mycology, College of Agriculture, Poona

AND

M. N. KAMAT

Assistant Mycologist, Bombay Department of Agriculture

(Received for publication on 27th September 1937)

(With Plates II—IV)

DURING the course of an investigation into powdery mildew in the Kaira district in Gujarat, cumin plants were observed to be dying along water-channels and in shady places in many fields. The affected plants had turned dark and completely withered. From the blighted plants a species of *Alternaria* was readily brought into pure culture. The fungus seemed new to science as there was no previous record of an *Alternaria* on *Cuminum cyminum* L. The results of a study of this fungus and the disease caused by it are described in the following pages.

THE DISEASE

The disease occurs sporadically and, although its causative agent seems to be widespread in the Kaira district, it has escaped notice since attacks are generally so slight as to be of no great economic consequence. The disease seems to be much influenced by humid conditions as the affected plants are commonly found along water-channels in a field or in situations with dense shade.

In the early stage of attack affected plants show minute, whitish necrotic areas which turn purple with age and later become brown and finally black. All aerial parts of the plant are involved, the extent of damage depending upon the time of appearance of the disease and the stage of maturity of the crop. The necrotic areas are exceedingly small in extent but, as they enlarge, become obliterated in the general invasion. The disease ultimately kills the affected parts, particularly the succulent leaves and blossoms. It is named blight because of the complete death of the tissues of the whole or part of the plant affected.

Blight usually appears about the middle of January when the crop is about two months old. If the disease appears at flowering, the whole crop may be destroyed providing wet weather prevails. Under such conditions affected plants rapidly wither and collapse into a pulpy mass. Infection is largely confined to the tips of the leaves but rapidly extends down to the stem during wet weather. In cases of severe attack affected plants bear no seed, but, if some seed is produced, it is usually shrivelled, dark coloured, light in weight and of poor germinability.

MORPHOLOGICAL CHARACTERS OF THE FUNGUS

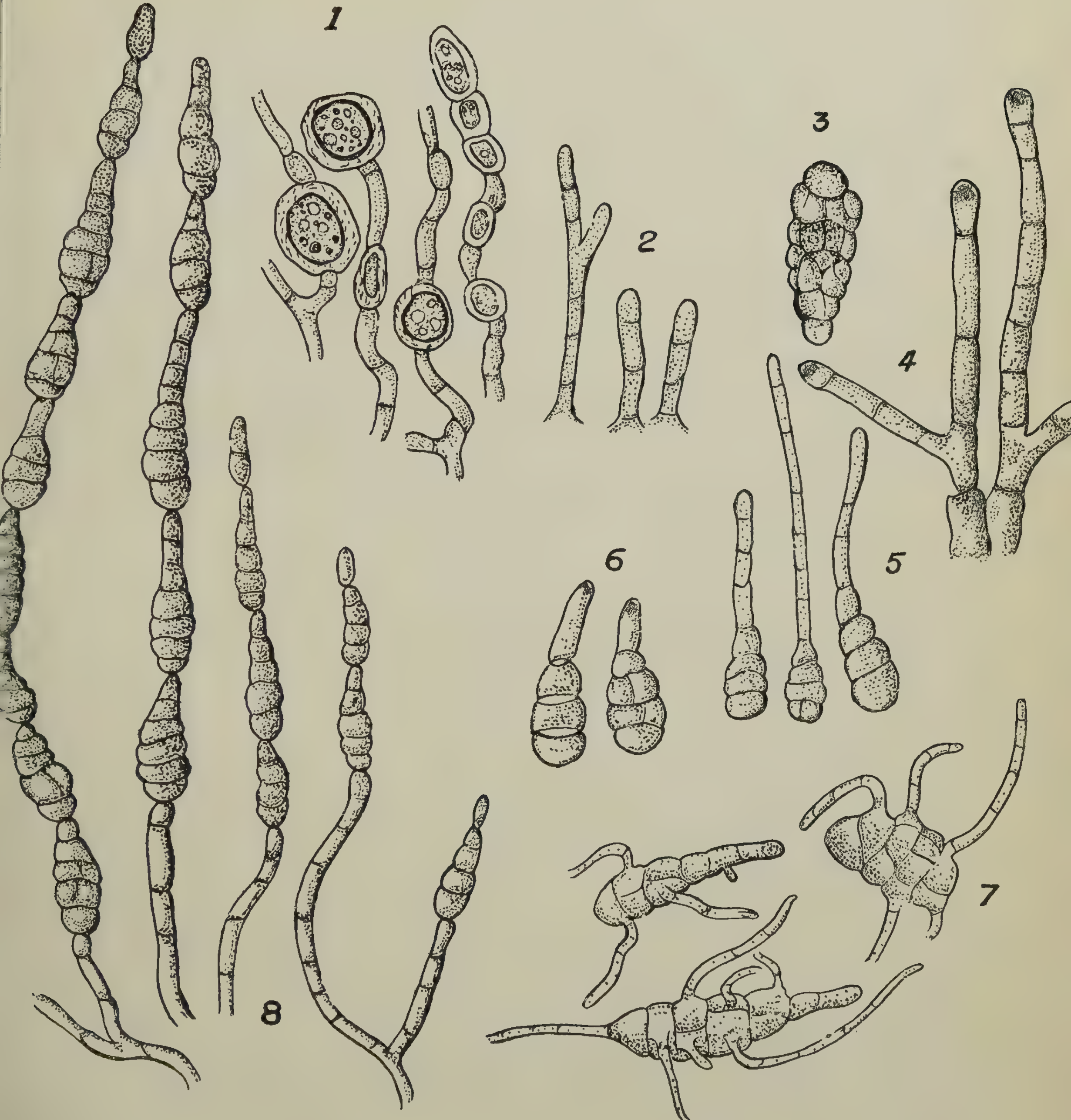
The mycelium shows considerable variations on different substrata. On potato-dextrose agar it is hyaline when young but later becomes light olive green. The diameter of the hyphae ranges from 1·7 to 5·8 μ. On oat-meal agar the mycelium shows a greater tendency to form chlamydospore-like bodies (Plate II, fig. 1). On cumin agar* the cells of the hyphae are thicker and richer in contents.

On the stem and leaf, the conidiophores develop either singly or in fascicles over the infected spot. They are usually simple, but may be branched (Plate II, fig. 2). They are erect, straight or somewhat irregularly bent, and geniculate, and measure from 1·9 to 3·7 μ in diameter and vary in length from 15 to 52 μ. Often masses of short, thick-walled cells are seen at the base of the conidiophore. In colour the conidiophores are light olive. A single terminal scar is sometimes found in the conidiophores, which are usually rounded at the tip (Plate II, fig. 4). In culture the conidiophores are 3- to 5-celled, the end cell being sometimes shorter than the rest ; though as many as eight cells are occasionally found in conidiophores produced on the host (Plate II, fig. 4).

In culture the conidia measure 13·8 to 55·1 × 6·9 to 25·2 μ (without beak) and 23 to 118·9 ×7 to 29·9 μ including the beak. The number of main cross-walls varies from one to nine but is usually three to five, and the cross septa can be easily made out by the constriction of the spore, except in the region of the beak. The conidia are borne in chains of two to ten (Ashby's agar), but catenulation is more common in older cultures (Plate II, fig. 8). They are sometimes obclavate but mostly obovate, with a rounded base and gradually tapering to the apex, which may be drawn into a septate or non-septate beak (Plate II, figs. 5 and 6), often as long as the conidium. Sometimes individual conidia develop a large number of longitudinal and oblique septa resulting in an irregularly shaped cell (Plate II, fig. 3). In colour the conidia are usually olive green. They germinate by germ-tubes which vary in number (Plate II, fig. 7).

---

* Cumin agar was prepared as follows : Sixty grams of cut pieces of young cumin plants were boiled in 1,000 c. c. of water and then strained through cheesecloth. To the clear broth two per cent agar was added and heated till agar was dissolved. The medium was sterilised at fifteen pounds pressure for fifteen minutes.



1. Hyphae showing enlarged, chlamydospore-like bodies (×520). 2. Simple and branched conidiophores (×780). 3. Irregularly shaped conidium due to a large number of longitudinal and oblique septa (×780). 4. Conidiophores from host 4″ to 8″ celled and showing terminal scars (×1000). 5. Conidia with septate beak (×780). 6. Conidia with non-septate beak (×780). 7. Germinating conidia (×780). 8. Conidia in chains of two to nine (×520).

On the host the conidia have never been observed in chains but are borne singly at the tips of conidiophores. They are fairly uniform in shape, being mostly obclavate, and are provided with long beaks. In dimensions they do not vary much from the conidia produced in culture, and are usually pale dirty brown in colour.

PHYSIOLOGICAL CHARACTERS OF THE FUNGUS

Germination of spores.—The conidia germinate readily in hanging-drop cultures of distilled water, and the rapidity with which necrotic lesions appear on the host in the field shows that the spores must start germinating almost immediately after alighting on the host surface. Germination in tap water was slightly inhibited, and the growth of the germ-tubes was also retarded. In media such as Richards's solution and a five per cent solution of cane sugar, there was no increase in germination over that obtained in distilled water.

Germination of conidia was studied in water cultures at various temperatures. The figures in Table I are the averages obtained from three tests and represent the percentages of germination at the end of four hours.

TABLE I

Effect of temperature on the germination of conidia of cumin Alternaria

Temperature (°C.)	Per cent of germination
1·5	0
4·5	trace
7·5	16·4
11·5	40
17	48·5
20	63·3
26-27	97·4
30	81·1
35	49·7
37·5	26·2
40	0

The conidia do not germinate in water at 1·5°C., but there is some measurable germination at 4·5°C. With further rise in temperature germination increases and is at its optimum at 26-27°C. It then falls off sharply and is completely suppressed at 40°C.

The effect of freezing on the germination of conidia was also studied. The exposure to freezing in a refrigerator was continuous over periods ranging from one to thirty-nine days, the average germination being calculated twenty-four hours after the transfer of cultures to room temperature. Germination was not appreciably retarded for exposures of eighteen days or of shorter duration, but it was inhibited in varying degrees with longer exposures and was hardly twenty per cent at the end of thirty-nine days' exposure.

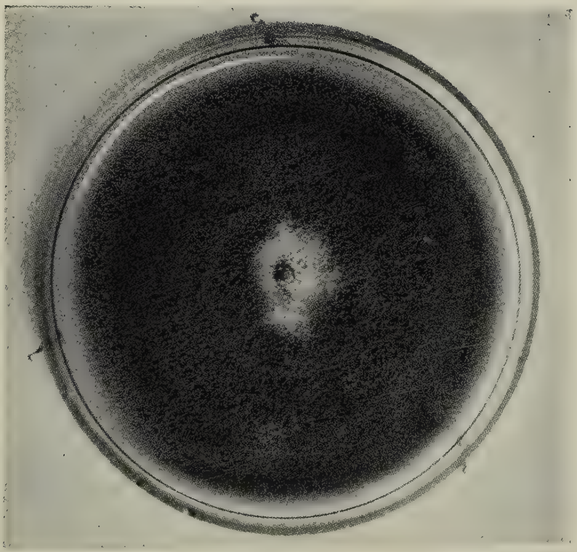
This evidence suggests that low temperatures during the growing season of cumin, which are generally many degrees above freezing, are not a factor in the germination of conidia and the subsequent infection of the host.

Growth on solid media.—Cultures derived from single conidia of cumin *Alternaria* were grown at room temperature (varying from 25° to 27°C.) on cumin agar, potato-dextrose agar, oat-meal agar, Richards's agar and boiled cumin seed.

The fungus grows freely on all culture media except boiled cumin seed. On cumin agar the centre of the colony has a deep purple grey tint and is surrounded by a light neutral grey zone. Towards the edge the colony becomes light yellowish. At the end of eight days the plate cultures show a distinct concentric arrangement of purple grey rings within the medium. The submerged mycelium is coloured, and there is prolific spore production, the conidia being borne singly or in chains of four or five. They are quite uniform in shape and pale brown in colour.

On potato-dextrose agar the fungus makes very vigorous and characteristic growth (Plate III), and a diameter of 6·5 cm. in ten days is recorded ; the colonies on oat-meal and corn-meal agars are about 5·5 cm. and 5·2 cm. in diameter respectively. The aerial mycelium is more freely developed on oat-meal, potato-dextrose and Richards's agars than on the other media, and after fourteen days the cultures are sporing freely. Zonation is marked on cumin agar but is not so distinct on potato-dextrose agar. The fungus produces a wide range of pigments in culture media. Except during the summer months, the fungus grows freely in culture at room temperature, varying from 25° to 27°C.

Growth at various temperatures.—The influence of temperature on the rate of linear growth of the fungus was studied. Equal quantities of potato-dextrose agar were poured deep in Petri dishes, and inoculum taken from the margins of a young growing culture was placed at the centre of these plates. The cultures were exposed to temperatures ranging from 1·5° to 37·5°C. for a period of one week, and were replicated to minimise possible variations. The results on the rate of growth of cumin *Alternaria* at various temperatures are given in Table II.



Eight-day-old culture of cumin *Alternaria* on potato-dextrose agar at 25-27°C. showing characteristic growth

TABLE II

Influence of temperature on the rate of growth of cumin Alternaria

Temperature (°C.)	Colony diameter (in cm.)
1·5	0
4·5	0·7
7·5	1·7
11·5	2·4
17	5·6
20	5·6
26-27	7·8
30	7·7
35	0·5
37·5	0

The range of temperature for growth is almost identical with that of spore germination. The fungus does not grow at 1·5°C., but makes definite, though slow, growth at a temperature range of 4·5° to 11·5°C. At higher levels the growth is rapid and reaches its optimum at 26° to 30°C., followed by a rapid fall above this range. The maximum temperature of growth is 35°C., growth being suppressed at 37·5°C.

During the growing period of cumin from November to February temperatures in the neighbourhood of 26° to 30°C. are generally experienced in the Kaira district, and the fungus makes greatest growth if the weather also turns out wet or humid. Under these conditions blight patches are more frequent along water-channels or in shady places promoting excessive humidity. There are, however, periods of very hot weather in summer, but, although the fungus makes no growth at and above 37·5°C., it can oversummer in exposed plant residues in the field as will be shown later.

Growth on plain agar containing different sources of carbon.—To equal quantities of two per cent plain agar various compounds of carbon were added in concentrations of one, two and three per cent. After sterilisation the media were poured in equal quantities into plates, which were inoculated with a small piece of inoculum from a young culture of the fungus and incubated at room temperature (26° to 27°C.). Measurements of colony diameter were made after seven days. The results shown in Table III are the average of two series of plates.

TABLE III

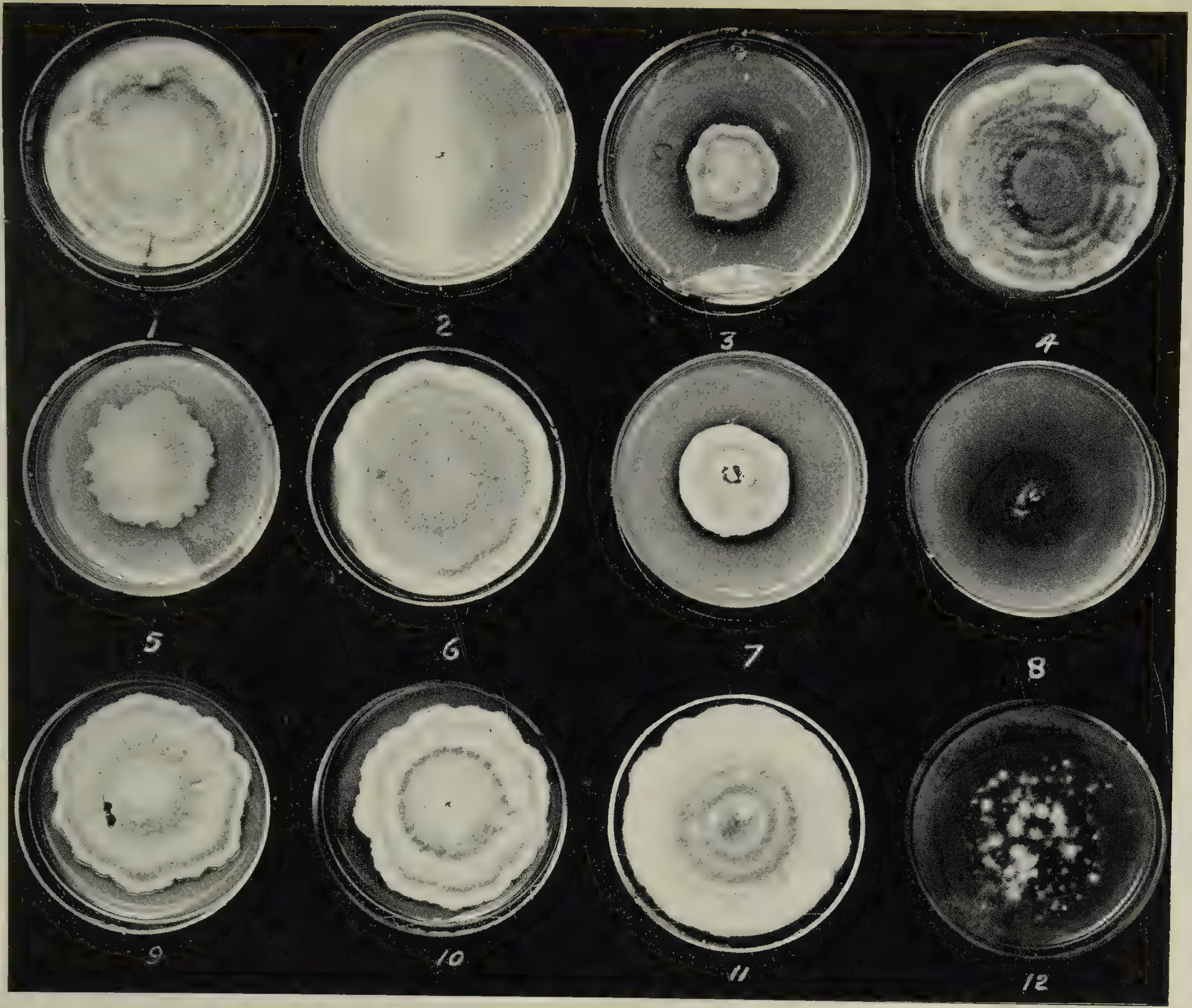
Growth of cumin Alternaria *on plain agar containing carbon compounds in different concentrations*

Source of carbon	Colony diameter (in cm.)		
	1 per cent	2 per cent	3 per cent
Sucrose	4·1	4·8	5·3
Lactose	4	5·1	5·3
Dextrose	4·6	4·7	5
Levulose	4·8	5·1	5·8
Maltose	6·8	7	7·2
Dextrin	5·8	5·8	5·8

With the exception of dextrin, the size of the colony increases with an increase in the concentration of the carbon compounds. The fungus grows profusely on maltose and dextrin in the order named. Levulose is also a favourable source of carbon as it supports vigorous growth. Lactose, sucrose and dextrose seem to be almost equally suited for growth. The fungus makes very feeble growth on plain agar, the diameter of the colony measuring barely 1·3 cm. after seven days. The fungus also produces pigment in the medium containing various sources of carbon, pigmentation increasing in intensity with higher concentrations of carbon. No pigment is produced on plain agar.

Growth on modified Richards's agar containing different sources of nitrogen.—The nitrogen metabolism of cumin *Alternaria* was studied. Modified Richards's agar (the medium from which potassium nitrate was omitted) was used as a base to which various compounds of inorganic and organic nitrogen of the highest purity were added in the concentration of one per cent. Equal quantities of each medium were poured in Petri dishes. All media were inoculated in duplicate, and plates were incubated at 26° to 27°C. At the end of seven days measurements of colony diameter were made and growth characters of the colonies were noted. The results are recorded in Table IV and illustrated in Plate IV.

PLATE IV



Growth of cumin *Alternaria* on modified Richards's agar containing (1) sodium nitrate, (2) sodium nitrite, (3) ammonium phosphate, (4) asparagin, (5) ammonium sulphate, (6) potassium nitrate, (7) urea, (8) ammonium nitrate, (9) ammonium lactate, (10) ammonium tartarate, (11) sodium asparaginate and (12) no nitrogen.

TABLE IV

Growth and colony characters of cumin Alternaria *on modified Richards's agar containing various compounds of nitrogen*

Source of nitrogen	Colony diameter (in cm.)	Colony characters*
Sodium nitrate	5·7	Growth sub-aerial, matted, sepia in the centre and pecan brown along sides. Concentric zoning. Margins irregular. Scanty sporulation.
Sodium nitrite	0	....
Ammonium phosphate, dibasic .	2·7	Growth raised, sepia with a narrow fringe of cinnamon buff. Scanty sporulation.
Asparagin	6·7	Growth dense matted, verona brown. Concentric zoning. Margins more or less irregular. Sporulation scanty.
Ammonium sulphate . . .	5	Growth flat, salmon buff. Margins irregular. No spores produced.
Potassium nitrate (Richards's agar)	6·5	Growth aerial, matted, liver brown in centre and orange cinnamon along sides. Concentric zoning. Margins more or less irregular. No spores produced.
Urea	3·5	Growth raised, Mars brown with a fringe of salmon buff. Margins regular. A few spores produced.
Ammonium nitrate . . .	4·5	Growth submerged, orange cinnamon. No spores produced.
Ammonium lactate . . .	6·7	Growth dense matted, Mars brown in centre and ochraceous orange along sides. Margins irregular. No spores produced.
Ammonium tartarate . .	6	Growth dense matted, orange cinnamon in centre and cinnamon buff along sides. Concentric zoning. Margins irregular. No spores produced.
Sodium asparaginate . . .	7·5	Growth aerial, matted, verona brown with a narrow fringe of pinkish cinnamon. Concentric zoning. Margins almost regular. No spores produced.
Modified Richards's agar (Control)	7·5	Growth fluffy in patches, greyish olive. Margins regular. No spores produced.

---

*Ridgway's colour nomenclature has been followed in describing colour production in the media.

The fungus makes the best growth on modified Richards's agar and on the medium containing sodium asparaginate, the diameter of colonies measuring 7·5 cm. after seven days. Asparagin, ammonium lactate, potassium nitrate (*i.e.*, Richards's agar) and ammonium tartarate are also suited for vigorous growth. Of all the compounds tested, sodium nitrite alone inhibits growth, and growths on media containing urea and ammonium phosphate are poor. An interesting feature is the production by the mycelium of the fungus of a variety of pigments in the media. The type of growth and topography of colonies also vary greatly with the different media. Zonation is marked in some media and absent from the others.

Growth in liquid media.—A series of flasks was set up containing 500 c.c. quantities of seven synthetic liquid media. The flasks were inoculated with a young growing culture of the fungus and incubated at room temperature, varying from 25° to 27°C. At the end of seven, twenty-one and thirty days the cultures were filtered and the mycelial mats were washed and dried between blotting paper and then over calcium chloride *in vacuo* for a week. The mats were finally weighed. The figures in Table V are the average of two series of flasks.

TABLE V

Dry weight of mycelial mats of cumin Alternaria

Culture medium	Dry weight of mat in grms. after		
	7 days	21 days	30 days
Meyer	1·312	1·796	3·580
Richards	0·630	0·887	2·385
Czapek	0·670	0·690	2·050
Pfeffer	0·492	0·347	0·875
Fermi	0·102	0·190	0·428
Coons	0·230	0·291	0·500
Cohn	0	0·025	0·025

Cumin *Alternaria* shows a wide range of growth in synthetic liquid media. The best growth occurs in Meyer's solution, and the fungus is also able to make good growth in Czapek's and Richards's solutions. Growth is very poor in Pfeffer's, Fermi's and Coons' solutions and is almost negligible in Cohn's.

Influence of hydrogen-ion concentration on rate of growth.—Richards's solution was made up and adjusted to different pH values by the colorimetric method. The flasks were inoculated with a young growing culture of the fungus and incubated at room temperature. After twenty days the dry weight of mycelial mats was determined and is shown in Table VI.

TABLE VI

Growth of cumin Alternaria *in Richards's solution at different* p*H*

*p*H	Dry weight of mat in mg.
1·2	0
2·8	trace
3	190
4·6	205
6	580
7	407
8	332
10	218

The fungus can grow in a wide range of hydrogen-ion concentrations, but it remains at rest in very high acid conditions. The range of optimum reaction appears to lie between *p*H 6 and 7, and in general the amount of aerial mycelium produced in culture is greater in acid than in alkaline reactions. This indicates that acid conditions are more favourable to growth than alkaline conditions.

THE ENZYMES OF CUMIN *ALTERNARIA*

For the investigation of the enzymes of the fungus, various media as described by Crabill and Reed [1915] were made up, and the plates of these media were inoculated at the centre with small pieces of inoculum taken from the edge of a young culture of the fungus and incubated at room temperature, varying from 25° to 27°C. The results are recorded in Table VII.

TABLE VII

Growth of cumin Alternaria *on different media*

Medium	Colony diameter (in cm.)	Reaction
Starch agar	7·5	Digestion, clear halo.
Inulin agar	6·5	Good growth and sporulation.
Amygdalin agar. . . .	6·5	Good growth.
Litmus cream agar . . .	8·5	Profuse growth, a sharp red reaction.
Casein agar	7	Good growth, complete digestion.
Egg-albumen agar . . .	3·5	Moderate growth, digestion.
Asparagin agar	3	No reaction, moderate growth.
Cellulose agar	..	Very slight growth.

On litmus cream agar a spreading growth and a zone of sharp red colour are produced. Starch is digested resulting in a 'halo' around the colony, and there is also good growth. Equally good growth is obtained on amygdalin agar. Casein is completely digested, the fungus growing and sporing freely on casein agar. Egg albumen supports growth but is not visibly digested by the fungus. On inulin agar the fungus makes good growth and also produces spores. Asparagin-rosolic acid agar supports growth but there is no colour reaction in the medium. On cellulose agar a very slight growth is obtained.

These results show that the mycelium of cumin *Alternaria* excretes the enzymes emulsin, erepsin, trypsin, amylase, lipase and inulase, thus indicating the ability of the fungus to utilise a wide range of food materials.

PATHOGENICITY

Isolation.—The material used in the present investigations was first collected in 1929 from a cumin field near Anand in Gujarat.

Scores of isolations were made during the course of this work, and in all cases a species of *Alternaria* was readily brought into pure culture. The material for isolation was carefully selected since it is somewhat difficult to isolate the fungus from the tissues of affected plants in an advanced state of decay.

Inoculation.—The infection experiments were performed on small plants which had been grown from sterilised seed. Spores and mycelium were used as the inoculum, and two different methods of inoculation were employed. In the first, cumin plants were sprayed with a spore suspension, and for a few days they were covered by bell-jars but in some cases the jars were removed after forty-eight hours. The second method consisted of spraying the plants with sterile water and painting masses of spores and mycelium on to the required spots with a sterilised brush. These plants were also kept under bell-jars. In another series small plants in pots were inoculated in the two manners indicated, but were not covered by bell-jars. The results of the experiments are recorded in Table VIII.

TABLE VIII

Infection experiments with cumin Alternaria *on cumin*

Method of inoculation	Whether or not covered by bell-jar	No. of plants inoculated	Per cent of infection
Spore suspension	Covered	4	75
Spore suspension	Covered	3	100
Spore suspension	Covered	4	100
Spore suspension	Covered	8	100
Spore suspension	Covered	54	90·7
Spore suspension	Not covered	3	33·3
Spore suspension	Not covered	4	0
Spore suspension	Not covered	8	0
Spore paint	Covered	8	100
Spore paint	Covered	3	66·6
Spore paint	Not covered	3	0

It will be seen from the table that the presence of moisture is essential for infection; if the plants were allowed to dry during the experiment, the growth of the fungus was checked and the inoculated plants grew away from the disease. The method of inoculation made no difference since infection readily occurred whether the inoculum was applied as a spore suspension or as a paint of spores and mycelium after the plants had been sprayed with sterile water. The fungus was re-isolated from infected plants. Controls were kept but in no case did these become infected.

CROSS INOCULATION

In order to test the host range of the fungus the following species of plants were inoculated simultaneously: *Foeniculum vulgare* Mill., *Coriandrum sativum* L., *Trigonella foenum-graecum* L., *Allium cepa* L., *Peucedanum graveolens* Benth., *Nicotiana tabacum* L., *Lycopersicum esculentum* Mill., *Capsicum* sp. and *Cuminum cyminum* L. For comparison a parallel series of inoculation was made with the cumin fungus. The plants were sprayed with spore suspensions and covered by bell-jars. In no case did the fungus infect any host other than *Cuminum cyminum*, in which case almost ninety per cent infection was obtained. The results are recorded in Table IX.

TABLE IX

Inoculation of various plants with cumin Alternaria

Species of plant inoculated	No. of plants inoculated	Per cent of infection
Foeniculum vulgare	45	0
Coriandrum sativum	45	0
Trigonella foenum-graecum	10	0
Allium cepa	18	0
Peucedanum graveolens	10	0
Nicotiana tabacum	2	0
Lycopersicum esculentum	2	0
Capsicum sp.	2	0
Cuminum cyminum (control)	40	87·5

OVERSUMMERING

In the absence of alternate hosts, cumin *Alternaria* may perennate on the seed or survive in exposed plant residues in the field. The ability of the fungus to survive long periods of dry conditions in the laboratory and out-of-doors was investigated. In January, 1933, infected stalks and seeds collected from cumin fields were wrapped in thick, brown paper and tied in muslin bags. Some of these bags were buried in the soil to a depth of about three inches near the Tobacco Breeding Station at Nadiad, and others were suspended in the air in one of the rooms of the Station. A sample of the infected stalks and seeds was also kept in the laboratory at Poona.

Numerous isolations were made from time to time during the summer months from the infected stalks and seeds buried in the soil or suspended aboveground at Nadiad. In all cases a fungus was obtained on potato-dextrose agar that resembled cumin *Alternaria.* In inoculation experiments this fungus was proved to be pathogenic on cumin seedlings grown in pots.

Isolations from the material kept in the laboratory at Poona were continued throughout the year, and invariably gave the typical *Alternaria* in culture. The pathogenicity of the various isolates was tested by inoculation to cumin seedlings.

These results suggest that cumin *Alternaria* can oversummer in exposed plant residues in the field and is able to withstand long periods of dry conditions in the laboratory. The critical period for the oversummering of the fungus lies in the months of April, May and early June when hot and dry weather conditions prevail in the Kaira district and maximum temperatures are generally in the neighbourhood of 109°F. With the advent of the monsoon the conditions for oversummering become favourable due to warm, cloudy periods accompanied by rain. It is, however, somewhat doubtful whether all the primary infection comes from exposed plant debris in the field since the soil in which cumin is grown as a *rabi* crop always receives a very clean tillage after the monsoon. It appears that infected seed must play an important role in the perennation of the fungus and in initiating primary infection.

TAXONOMY AND DIAGNOSIS

There is no previous record of an *Alternaria* on *Cuminum cyminum* L., and so far as it has been possible to determine with the help of herbarium specimens, none of the described species of *Alternaria* and *Macrosporium* compare with the *Alternaria* on cumin. The nearest species to the latter is *Alternaria longipes* (Ell. & Ev.) Tisdale and Wadkins [Tisdale and Wadkins, 1931], which produces spores of about the same size and shape as the cumin fungus, and also has a beak rather like that of the latter. But *A. longipes* has a short beak on the host and practically no beak in culture [Wiltshire, 1933]. Cumin *Alternaria*, on the other hand, produces quite a long beak. *A. longipes* is definitely pathogenic on tobacco, whilst tobacco has always failed to take infection in cross-inoculation experiments with the cumin fungus.

The foregoing considerations seem to justify establishing this fungus as a new species. It is proposed to name the fungus after Dr. W. Burns, a pioneer investigator and organiser of plant pathological research in the Bombay Presidency.

ALTERNARIA BURNSII SPEC. NOV.

Mycelium on potato-dextrose agar from 1·7 to 5·8 μ in diameter, septate, hyaline when young but later becoming light olive green.

Conidiophores, solitary or fasciculate, erect, simple or sometimes branched, light olive, septate, straight or somewhat irregularly bent, occasionally with a single terminal scar, geniculate, 3- to 5-celled (occasionally 8-celled on host), measuring 15 to 52 × 1·9 to 3·7 μ.

Conidia borne singly on the host but in chains of two to ten in culture, mostly obovate or rarely obclavate, with rounded base, tapering to the apex which may be drawn into septate or non-septate beak, often as long as the spore ; septate with transverse, longitudinal and oblique septa, from one to nine, mostly three to five, transverse septa, constricted at the septa (except in the region of the beak), olive brown, measuring 13·8 to 55·1 × 6·9 to 25·2 μ (without beak) and 23 to 118·9 × 7 to 29·9 μ including the beak.

In living branches, leaves and fruits of *Cuminum cyminum* L. in the Kaira district in Gujarat, Bombay Presidency.

Hyphis, in agaro ‘ potato-dextrose ’ cultis, septatis, primo hyalinis, dein pallide olivaceo-viridibus, 1·7-5·8 μ crassis. Conidiophoris solitariis vel fasciculatis, erectis, simplicibus vel interdum ramosis, pallide olivaceis, septatis, rectis vel subsinuosis, raro cicatrice singulo apicali praeditis sed plerumque geniculatis, 2-4 (raro in hospite ad 7) septatis, 15-52 μ longis, 1·9-3·7 μ latis. Conidiis in hospite singulis, in agaro 2- ad 10-catenulatim productis, plerumque obovatis, raro obclavatis, basi obtusis, ad apicem, qui in rostrum aequilongum, 0-vel pauce-septatum, aliquando abit, teretibus ; 1-9 (plerumque 3-5) transverse-, etiam longitudinale- et and oblique, septatis, ad septa (nisi in rostro) constrictis, olivaceo-brunneis, 13·8-55·1 × 6·9-25·2 μ (erostratis), 23-118·9 × 7-29·9 μ (rostratis).

In ramis, foliis, fructibus vivis *Cumini cymini* L. ; Gujarat, Bombaii, Indiae or.

Type material deposited in the herbaria of the College of Agriculture, Poona, and of the Imperial Mycological Institute, London.

SUMMARY

Alternaria blight of cumin occurs sporadically in the Kaira district. The disease seems to be much influenced by humid conditions as the affected plants are commonly found along water-channels or in shady places in a field.

All aerial parts of the plant are attacked. In the early stage of the disease the affected plants show minute, whitish necrotic areas which turn purple with age and later become brown and finally black. These areas are first exceedingly small in extent but, as they enlarge, become obliterated in the general invasion. The disease ultimately kills the affected parts, particularly the succulent leaves and blossoms. It is named blight.

Wet weather favours the development of the disease which may assume serious proportions if it appears at flowering. The attacked plants bear no seed, but, if some seed is produced, it is usually shrivelled, dark coloured and of poor germinability.

The morphology and cultural characters of the causative organism have been described. The mycelium of the fungus produces the enzymes emulsin, trypsin, erepsin, amylase, lipase and inulase.

The fungus is extremely pathogenic on cumin, but the presence of moisture is essential for successful infection. Cross-inoculation experiments with the cumin fungus gave negative results.

The fungus is able to oversummer in plant residues in the field. It is probable that infected seed also plays an important part in the perennation of the fungus and in initiating primary infection.

The fungus is a new species of *Alternaria*, and the name *Alternaria burnsii* is proposed for it. A description of the fungus is given together with a Latin diagnosis.

In conclusion the writers wish to thank Dr. S. P. Wiltshire for kindly undertaking (as far as possible) the comparison of cumin *Alternaria* with the exsiccata of *Alternaria* and *Macrosporium* spp. recorded on the Umbelliferae. They are also grateful to Mr. S. F. Ashby, Director, Imperial Mycological Institute, for valuable assistance in various ways and to Mr. E. W. Mason for the Latin rendering of the description of the fungus.

REFERENCES

Crabill, C. H. and Reed, H. S. (1915). *Biochem. Bull.* **4**, 30-44.
Tisdale, W. B. and Wadkins, R. F. (1931). *Phytopath.* **21**, 641-660.
Wiltshire, S. P. (1933). *Trans. Brit. Mycol. Soc.* **18**, 135-160.

THE *TUR*-POD FLY, *AGROMYZA OBTUSA* MALL., A PEST OF *CAJANUS CAJAN*

BY

TASKHIR AHMAD, PH.D. (CANTAB.)
Assistant Entomologist, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 20th August 1937)

(With Plate V)

CONTENTS

PAGE
I. INTRODUCTION 63
II. SYSTEMATIC POSITION AND DIAGNOSTIC CHARACTERS . . . 64
III. DISTRIBUTION 65
IV. NATURE AND EXTENT OF DAMAGE 66
V. LIFE-HISTORY 67
1. Copulation and oviposition 67
2. Number of eggs 67
3. Egg stage 68
4. Larval stage 69
5. Pupal stage 71
6. Adult stage 72
7. Number of broods and seasonal history 73
VI. PARASITES 74
VII. CONTROL MEASURES 75
VIII. ACKNOWLEDGMENTS 75
IX. SUMMARY 75
REFERENCES 76

I. INTRODUCTION

IN spite of the fact that the *Tur*-pod fly was discovered as an important pest of *Cajanus Cajan* in India over thirty years ago, no attempt seems to have been made to determine its specific identity, exact life-history, and bionomics. It was first collected and reported by the Entomological Assistant, Nagpur, Central Provinces, when Lefroy [1906] recorded it under the name of '*Tur*-pod fly'. Later on it was also found at Pusa and several places in South India. Fletcher [1914] appended a sketch showing the nature of oviposition, and added a few lines on its life-history, but the identity of the species still remained unknown. He gave the name 'Red-gram Agromyza' instead of '*Tur*-pod fly', probably because he was not sure whether he was dealing with the same or a different species in the second case. About twelve years after the discovery of the pest, Andrews [1918] recorded it as a small black fly of the family Agromyzidae, the larvae of which feed on the seeds of *Cajanus Cajan*, but did not advance our knowledge about its life-history, nor determined its specific identity.

In March 1936, pods of *tur* (*Cajanus Cajan*) at Pusa were found heavily infested by the various stages of this fly. This opportunity was taken to work out its life-history both under laboratory and controlled environmental conditions. The flies bred therefrom were sent to the Imperial Institute of Entomology, London and have recently been received back, identified as *Agromyza obtusa* Mall.

Fortunately most of the material with which the previous workers in India had been dealing is still in the Pusa collection and therefore available for study. After comparison with the named specimens I am able to say that all the workers named above had the same species under investigation, *viz.*, *Agromyza obtusa*. All the previous information on the files of the Imperial Entomologist about this species and my own observations taken during 1936-37 are summarized in the following pages.

II. SYSTEMATIC POSITION AND DIAGNOSTIC CHARACTERS

The family Agromyzidae to which *Agromyza obtusa* belongs is characterised, according to the recent description of Curran [1934], by the following important characters :—

> "Head usually higher than long, front with at least 3 pairs of bristles ; ocellars and postocellars present, the latter divergent ; antennae decumbent, the third segment rarely much longer than wide. Oral vibrissae present. Legs short, the femora with bristles. Wing venation complete or the posterior cross vein absent".

Agromyza obtusa was first described by Mallock in 1914 from six specimens sent to him from Formosa, Japan. It seems curious that since 1914 there is no record of this species from any part of the world and yet it has been occurring as an important pest in several parts of India. Regarding the diagnostic characters of this species Mallock's description is reproduced.

> "*Male* : Glossy black. Frons opaque black, orbits and frontal triangle glossy black, with a slight greenish tinge ; frontal lunule white pollinose ; antennae, arista, and palpi black, proboscis brown at apex. Mesonotum and pleurae with a blue-green tinge, which at some angles presents a violaceous shade. Abdomen glossy black, the surface metallic, in some lights bronzy, in others with a violaceous tinge on a greenish-blue ground. Legs shining black. Wings clear, veins brown, yellowish at their bases. Squamae white, fringe concolorous. Halteres black.
>
> Frons very slightly over one third the width of head, frontal triangle broad and well defined, its sides gradually converging anteriorly, and slightly convex ; orbits distinct, with slight swellings at the bases of the bristles, 4 pairs of orbitals present, which are very stout and decrease but little in strength anteriorly, the anterior two pairs directed inwards, the two posterior pairs directed backwards ; antennae of moderate size,

second joint with the dorsal bristle distinct, third joint rounded ; arista slightly tapering at base of last section, the pubescence distinct, very fine, and not closely placed ; eyes pubescent, a small area on the upper surface very distinctly haired ; cheek almost linear, slightly higher on the posterior half, marginal hairs very numerous, but not strong, the vibrissa not differentiated. Mesonotum with 2 pairs of strong dorso-centrals, and sometimes a weak pair of setulae in front of the anterior pair, discal hairs short and closely placed, 8-10 rather irregular rows between the anterior dorso-centrals ; no distinct bristles between the posterior dorso-centrals. Abdomen broadly ovate, discal hairs strong and numerous, but not long ; hypopygium normal, legs strong, femora slightly thickened ; fore-tibia with a short setula on the posterior surface at about the middle mid tibia with the two posterior setulae present, but not very strong. Wings of normal breadth ; inner cross vein at, or very slightly on either side of the middle of the discal cell ; last section of fourth vein about 3 times as long as the penultimate section ; last sections of veins 3 and 4 slightly divergent ; last section of fifth vein about three fifths as long as penultimate section.

Length.—2·75-3 mm.

Female.—Similar in coloration to the male. Differing as follows ; the eyes are very indistinctly pubescent ; the orbits have more distinct short surface hairs than in the male, in addition to the bristles ; the ovipositor is much exerted and rather tubular ; the wings are slightly broader, and the third and fourth veins more distinctly divergent apically.

Length.—2·75-3·5 mm."

III. DISTRIBUTION

Agromyza obtusa is widely distributed throughout India. We have authentic records of its occurrence from the following localities (Table I).

TABLE I

Distribution of Agromyza obtusa *in India*

Locality	Province	Time of occurrence	Status
Nagpur . . .	C. P. .	January . .	Serious
Pusa . . .	Bihar .	March-April .	Do.
Patna . . .	Bihar .	April . .	Minor pest
New Delhi . .	. .	October-April .	Serious
Karnal . . .	Punjab .	February-March .	Fairly common
Bombay . . .	. .	. .	. . . .
Settigunta . .	Madras .	February . .	. . . .
Coimbatore . .	Madras .	. .	. . . .
Tocklai & Borbhetta .	Assam .	April . .	Minor pest
Burma . . .	. .	. .	Minor pest but causing large aggregate damage

It is interesting to see that while the fly occurs in widely different climatic regions of India, all existing records show that it is in evidence only during winter and spring.

This indicates that it is a sub-tropical insect with a rather low threshold of development and probably aestivates during summer.

IV. NATURE AND EXTENT OF DAMAGE

The young larvae of this fly, on hatching from the eggs which are laid inside the *tur* pods, find themselves directly on the soft seed into which they feed. At first their damage resembles that of leaf-miners, as their galleries run just under the epidermis of the seed. Gradually the larva grows and, when it becomes well developed, it burrows deeper down, consuming the starchy food as well as the embryo and depositing excreta therein. The damaged seeds thus become unfit for consumption or germination.

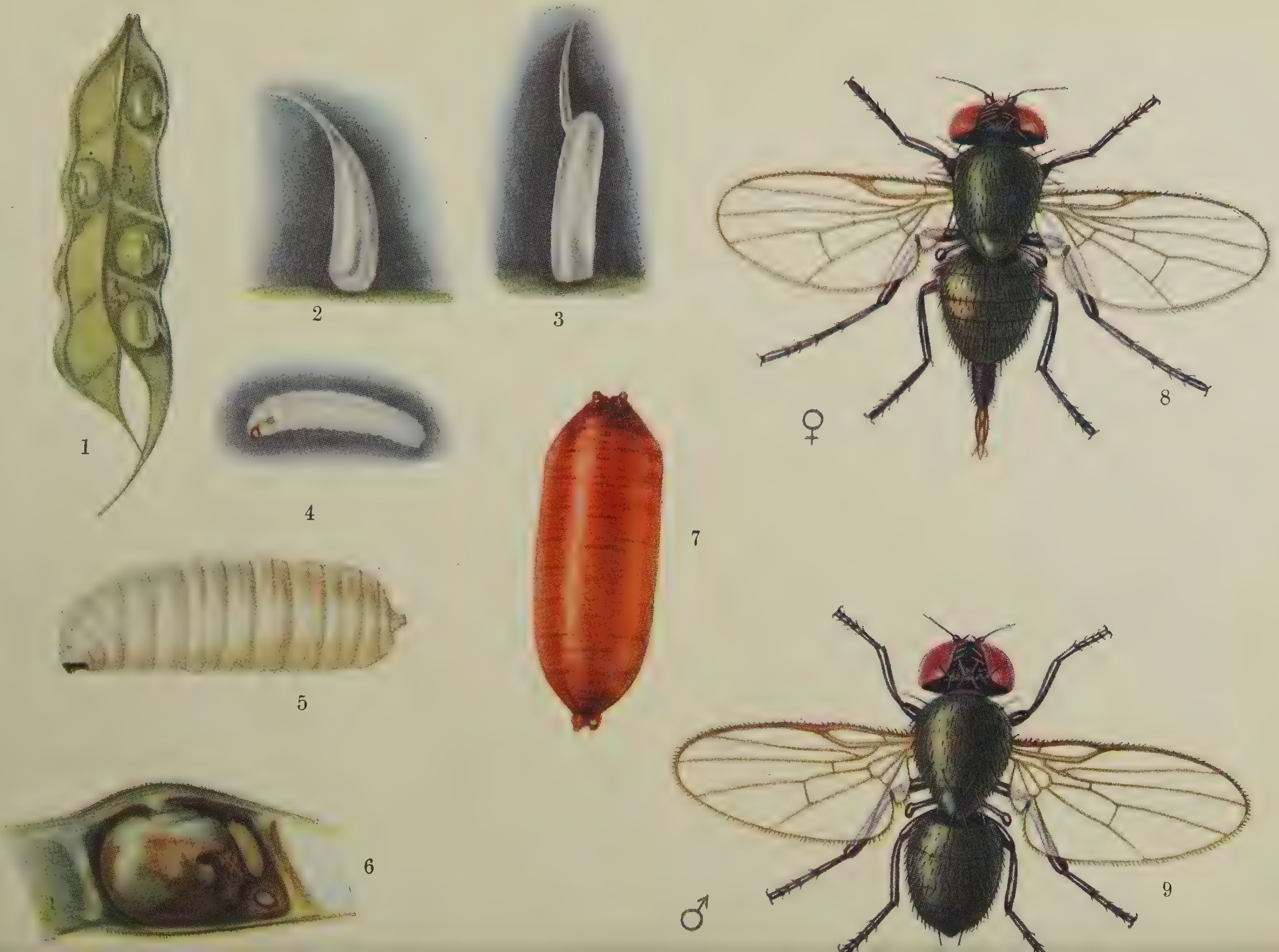
In the earliest record of this pest from Nagpur (Central Provinces) the damage to pods of *tur* was estimated at about 12·5 per cent of the whole crop. Lefroy [1909] considered it as an important enemy of farmers, while Schroff [1919] designated this fly as a minor pest of *tur* crop, but causing large aggregate damage. Our recent observations at Pusa and Delhi show that these estimates of the extent of damage are not at all exaggerated : in serious cases the damage may be as high as sixty-three per cent of the grains (Table II).

TABLE II

Extent of damage to tur *pods by* Agromyza obtusa

Locality	Date of observation	No. of pods		Per cent affected pods	No. of grains		Percentage of damaged grains
		Examined	Affected		Examined	Affected	
Pusa .	27th March 1936.	100	83	83	273	142	52·0
	28th March 1936	50	42	84	115	49	42·6
	30th March 1936	100	79	79	233	97	41·6
	1st April 1936 .	100	86	86	303	192	63·4
New Delhi	16th January 1937.	100	28	28	153	18	11·8
	18th January 1937.	100	32	32	318	36	11·3
	21st January 1937.	100	28	28	152	17	11·2
	15th February 1937.	100	12	12	149	10	6·9
	7th March 1937	100	50	50	160	62	38·7
	15th March 1937	100	54	54	158	57	36·1
	1st April 1937 .	100	59	59	166	71	42·7
	15th April 1937	100	31	31	142	35	24·9

Agromyza obtusa MALL.



Explanation of Plate V

Agromyza obtusa Mall.

Fig. 1. Pod of *Cajanus Cajan* opened to show oviposition (actual size)

Fig. 2. Egg, freshly laid (×45)

Fig. 3. Egg, fully developed (×45)

Fig. 4. Larva, freshly hatched (×45)

Fig. 5. Larva, full-grown (×15)

Fig. 6. Damaged seed in the pod and the hole for the emergence of fly (×1½)

Fig. 7. Pupa (×15)

Fig. 8. Adult fly, female (×15)

Fig. 9. Adult fly, male (×15)

At Pusa about eighty per cent of the pods and forty to sixty per cent of the grains were affected during March and April, 1936. This was, of course, towards the end of the season. At New Delhi, where the pest has been under observation during winter and spring, it appears that in December and January the activity of the insect is low, the percentage of grains damaged being only about eleven in January, rising to 42·7 in the beginning of April. It must be mentioned that, since the great majority of pods appear from February onwards, there are only few pods which mature prior to this intense activity of the pest.

V. LIFE-HISTORY

1. Copulation and oviposition

Soon after emergence from pupae, the flies are almost sexually mature. They therefore start copulation within twenty-four hours after emergence, usually during the first night. This lasts for about an hour or two and is followed by oviposition. In the *tur* fields a large number of flies are often seen early in the morning, hovering about from pod to pod, trying them one after the other and then suddenly sitting on one of them. This selection is not aimless but seems to be directed towards avoiding very young as well as advanced pods. Andrews [1914] recorded that the eggs are laid in the setting flowers or in very young pods. Very probably this statement is a surmise not based on observations, because the writer never observed eggs being laid in setting flowers or in very young pods. Having selected the right type of pod as mentioned above, the female pierces with her ovipositor the pericarp, and lays a single egg. It retracts the ovipositor and repeats the process at another spot. The posterior end of the egg is thus deposited firmly into the hole made in the pericarp, and when a pod is opened the eggs appear like needles projecting from the walls of the pod (Plate V, fig. 1).

2. Number of eggs

Freshly emerged flies were left overnight and pairs actually mating next morning were separated. Pods of suitable size formed from sleeved flowers and therefore known to be free of any eggs were supplied to each pair, caged in glass chimney cages. The number of eggs laid by six such pairs are given in Table III.

TABLE III

Number of eggs laid by a female

Experiment No.	Date of emergence of pair	Number of eggs laid each day					Total number of eggs	Remarks
		1st	2nd	3rd	4th	5th		
1	16th March 1936.	2	20	28	..	..	50	Fly escaped on 20th March 1936.
2	20th March 1936.	6	2	13	3	..	14	Died 5th day.
3	22nd March 1936.	1	5	7	20	..	33	Died 5th day.
4	24th March 1936.	1	6	2	11	..	20	Died 7th day.
5	27th March 1936.	2	7	22	..	..	31	Died 5th day.
6	1st March 1937	4	22	28	25	..	79	Died 6th day.
					Average		38	

It will be observed that the life of adults being rather short, the period of active oviposition is limited to three to four days only. The number of eggs laid during the first twenty-four hours is minimum, being one to six per female. It goes on steadily increasing so that eggs during the 3rd and 4th day form seventy per cent of the total oviposition. The maximum number of eggs laid by a female during her life was seventy-nine, the average being thirty-eight. In captivity, where a single pod was supplied to the female, the maximum number of eggs laid in one pod was thirty-two, but in nature such a high figure was never reached. The average number of eggs per pod in the field was four and the maximum seven.

3. *Egg stage*

The freshly laid egg is white, broad and rounded at the posterior end which is embedded in the tissue of the pod and narrowed anteriorly into a somewhat curved elongated hollow process (Plate V, fig. 2), which is nothing but an extension of the egg sheath. As the egg develops, this process is pushed aside and, under the pressure of the developing embryo, the anterior end also becomes rounded (Plate V, fig. 3). The egg in this condition, without the process, measures 0·66 mm. in length and 0·15 mm. in thickness.

Incubation period.—As the eggs are laid inside the pods they are well protected against atmospheric desiccation. They fail to develop if the pods are cut open and the eggs are exposed to a partially saturated atmosphere. Eggs could therefore be incubated in 100 per cent relative humidity only, and were so incubated at different constant temperatures as well as room temperature, and the results are given below (Table IV).

TABLE IV

Incubation period of Agromyza obtusa *at different temperatures*

Temperature	No. of observations	Incubation period (days)	
		Range	Mean
27°C.	93	2·8—3·2	3·0
22°C.	78	3·3—4·2	4·0
18°C.	53	9·0—10·0	9·6
Room temp. (23°-28°C.)	44	3·0—3·33	3·1

The average incubation period was 3·0, 4·0 and 9·6 days at 27°C., 22°C. and 18°C. respectively. In the laboratory at Pusa during April, when the temperature fluctuated between 23° and 28°C., the incubation period was 3·1 days.

4. *Larval stage*

The freshly hatched larva (Plate V, fig. 4) is white, excepting its mouth parts which are dark brown, and which soon turn black. It measures a little less than the full-developed egg, the average measurements being 0.61 mm. in length and 0·12 mm. in thickness. The head is bent downwards so that when seen from above the mouth parts are not visible. The body consists of three thoracic and nine abdominal segments. A fine brownish stripe runs along the entire mid-dorsal line of the body. The anterior and posterior spiracles lie on the sides of the first thoracic and last abdominal segments respectively.

Young larvae on hatching attach themselves to the soft seeds inside the pods and for the first few hours do not bore into the seed but feed on the surface. Soon after they mine into the seed like leaf-miners, their galleries running just under the epidermis of the seed. It is interesting to find that these galleries, full of faecal matter and some uneaten starch, appear like dirty white bands encircling it and are usually placed at right angles to the filament of the seed. As the larva grows and becomes well developed, it feeds deeper into the seed and even damages the embryo, but so long as it is inside the grain, externally the latter may appear undamaged and complete. On careful examination, however, the burrow of the insect can be distinctly made out and an occasional quivering of the testa locates the place where the larva is feeding. When full grown, the larva comes out of the seed and the hole of exit may be clearly seen. One seed is quite sufficient for the complete development of the larva and though in rare cases a larva may move from one seed to the next, it never leaves the pod in which it is born and thus passes its entire larval life in the same pod. As already mentioned the eggs are laid at a definite stage of pod's development : therefore the larvae are also restricted to pods of medium size only, *i.e.*, pods containing soft green seeds but not tough mature grains. In advanced cases of damage, the pods present a twisted appearance by which they can be distinguished from others.

The full-grown larva before pupating comes out of the seed and eats a partial hole into the wall of the pod to enable the future fly to escape. This hole does not communicate with the exterior but a thin circular layer of epidermis is left intact (Plate V, fig. 6) to be forced through by the emerging fly. The larva may either pupate on the groove of the seed itself or very close to the hole mentioned above with the head end directed towards the hole.

The full-grown larva (Plate V, fig. 5) is sub-cylindrical, narrower at the head end which is as usual bent downwards and bears dark black mouth parts. The colour of the body is creamy white but acquires a yellowish tinge just before pupation. It measures 3·5 to 4 mm. in length and 1·25-1·5 mm. in thickness. The larva is amphipneustic, the anterior pair of spiracles being placed at sides of the first thoracic segment and the posterior pair of spiracles on the last abdominal segment. Each abdominal segment of the body bears a transverse furrow, which subdivides it into two, and therefore to all appearance one sees double the actual number of segments.

The larval period.—With regard to the influence of humidity what has been said of eggs is also true of the larval stage. The entire larval stage is passed within the closed pod and is, therefore, well protected from atmospheric desiccation. Under laboratory conditions it was easy to determine the duration of the larval stages by introducing freshly hatched larvae inside suitable pods on living plants and closing them securely and sleeving the pod. The pods were left undisturbed till the larvae became well developed. Thereafter they were examined daily to observe the time of pupation. Thus, the young stages which are most sensitive to disturbance were not molested and their development proceeded quite normally. But several difficulties confronted the determination of the larval stages in constant-temperature incubators. The pods severed from the plant and kept in the incubator began to rot within two to three days. On the other hand it was impracticable to keep living plants inside the incubators. This entailed frequent transference of larvae from old grains to fresh ones. The young larvae, on account of their highly sensitive and tender nature, were unable to stand this disturbance and thus underwent exceptionally high mortality and variable development. Nevertheless, several individuals were successfully reared to the pupal stage and the results of rearing are summarized in Table V.

TABLE V

Larval duration of Agromyza obtusa *at different temperatures*

Temperature	No. of observations	Larval duration (days)	
		Range	Mean
27°C.	16	8·83—11·83	9·8
Room temp. (23°—28°C.) . . .	49	5·66— 6·66	6·1
Room temp. (17°—21°C.) . . .	4	18·0 —21·0	19·1

Thus the average larval duration at Pusa during March and April at room temperature ranging between 23°C. and 28°C., when the pods were allowed to remain on living plants and the larvae developed undisturbed, was 6·1 days, the minimum being 5·7 days. During December, the larval duration was eighteen to twenty-one days. In the incubator at 27°C., where the pod had to be changed every forty-eight hours, the duration varied from 8·8 to 11·8 days with an average of 9·8 days. These observations, while giving an idea of the rate of development at different temperatures, show clearly the slackening in development caused by the disturbance of the larvae.

5. *Pupal stage*

A couple of hours before pupation the locomotion of the larva ceases. The puparium is yellowish white when freshly formed, but gradually becomes dull or creamy yellow. It assumes a reddish brown colour after about twenty-four hours and becomes darker after another forty-eight hours (Plate V, fig. 7). It is cylindrical and broadly rounded at the two ends. It measures 2·5 mm. in length and 1·25 mm. in thickness. The pupa is enclosed in this hard chitinous puparium which is attached to the side of the pod by means of a sticky exudation from the pupating larva.

The pupal period.—The response of the pupal stage of *Agromyza obtusa* to various environmental conditions is different from that of the egg and the larval stages in certain respects. The pupae are more resistant to desiccation and can therefore stand reasonable exposures to partially saturated atmosphere. They were able to complete development when exposed to 3 mm. saturation deficiency throughout the pupal period at 27°C. (Table VI).

TABLE VI

Pupal duration of Agromyza obtusa *under different conditions*

Temperature	Saturation deficiency	No. of observations	Pupal duration (days)	
			Range	Mean
27°C.	3 mm.	27	8·0— 9·0	8·7
27°C.	0 mm.	24	7·3— 9·0	8·4
18·5°C.	0 mm.	23	28·0—29·0	28·6
18·0°C.	0 mm.	17	28·7—32·0	30·5
Room temp. (23°—28°C.) . .	0 mm.	58	8·0—10·0	8·9
Room temp. (17°—21°C.) . .	0 mm.	6	19·3—24·7	22·7

Under natural conditions too, the pupal stage of the fly coincides with the ripening and drying up of the pods and the viability of the pupae is not impaired in this dry environment. Again the pupal stage is comparatively long or in other words the rate of pupal development is slower than that of the egg or the larval stage.

In a saturated atmosphere the average pupal period was 8·4 days at 27°C. (8·7 days at 3mm. saturation deficiency), 28·6 days at 18·5°C., 30·5 days at 18°C., 8·9 days at room temperature (23°C.-28°C.) during March-April and 22·7 days during December-January (17°C.-21°C.).

6. *Adult stage*

After emergence from the pupal case the adult fly makes its way towards the hole made by the full-grown larva in the pod with the epidermis still intact; probably by virtue of the positive heliotropism, it is attracted towards the light coming from the hole. It breaks the membrane and thus comes out. In the freshly emerged fly the wings are crumpled: it takes fifteen minutes or so to get them fully expanded. The body colour is dull white with smoky patches at places. The normal black colour is assumed in an hour or so when it also becomes capable of taking normal flight (Plate V, figs. 8, 9).

Longevity of adults.—The life of flies is rather short if kept without food. It is somewhat prolonged when a solution of honey is supplied as food,

TABLE VII

Longevity of Agromyza obtusa *adults under different conditions*

Temperature	No. of observations	Longevity in days	
		Range	Mean
A. Without food			
27°C.	35	2·7—4·0	3·35
22°C.	60	3·0—5·2	4·1
18°C.	39	5·3—8·0	6·8
Room temp. (23°-28°C.)	45	2·0—4·3	3·4
B. With honey solution as food			
27°C.	57	3·9— 6·8	5·4
22°C.	33	4·0—11·8	7·4
18°C.	32	6·0—20·2	11·9
Room temp. (23°-28°C.)	38	6·8—14·0	8·7

From Table VII, it will be observed that when kept without food the flies lived an average life of 3·35 days at 27°C., 4·1 days at 22°C., 6·8 days at 18°C., and 3·4 days at room temperature (23°-28°C.) during March-April. When cotton wool soaked in a dilute solution of honey was supplied they lived 5·4 days (maximum 6·8 days) at 27°C., 7·4 days (maximum 11·8 days) at 22°C., 11·9 days (maximum 20·2 days) at 18°C. and 8·7 days (maximum 14·0 days) at room temperature in March-April. Temperatures lower than 18°C. have not been tried and it is likely that during winter, when such temperatures prevail, the life of adults is further prolonged.

7. *Number of broods and seasonal history*

From the data presented in preceding tables it is evident that at a temperature of 27°C. and at laboratory temperature (23°-28°C.) during March-April, the pre-imaginal duration is only about three weeks. Adding the pre-oviposition period of one to two days we get the duration of a single brood as twenty-two to twenty-three days. From this, it is easy to realise the rapidity with which the broods are completed and the manner in which number of flies swells under favourable conditions. It will be further noticed that development goes on even at 18°C. though at a considerably slow rate : the pre-imaginal stages requiring a period of well over two months. These results are supported by field observations.

For the first time the flies were observed in field in October and November and with the commencement of pod formation in October, the first batch of eggs was found laid on 11th October. Oviposition continued till about the end of November when it stopped altogether. Thus, during December and January, with the exception of a few full-grown larvae and pupae, no other stage of the fly was noticeable. Evidently the larvae hatched from eggs laid in October-November had pupated or were going to pupate and it was in this pre-pupal or pupal stage that the severe winter was passed, development going on at a slow rate. Of a large number of pupae collected during January, majority were found dead : only about five per cent were viable. From these pupae the flies commenced to emerge in the laboratory, during first week of February. In field also adult flies were in evidence during the 2nd week of February and first batch of eggs was found on 15th February 1937. The development and multiplication of flies quickened thereafter and was at its peak during March and April. It completed two to three broods before *tur* crop was harvested towards the end of April. It is not known how the fly passes the period from May to September : whether it aestivates during the hot weather or passes on to some alternate food plants, has yet to be ascertained. An allied species, *Agromyza andalusiaca*, a pest of artichoke in Italy and Spain has normally three broods in a year, behaving somewhat similar to *Agromyza obtusa*. The adults of the first brood emerge in December, those of the 2nd in March-April and the adults of the third do not appear until after the end of summer, *viz.* in October. Under certain conditions, particularly abundant moisture, there may be only two broods in a year, the pupal stage of last being greatly prolonged [Richhello, 1928].

VI. PARASITES

Two chalcid parasites and a third which is presumably a hyperparasite, have been reared out of the larvae of *Agromyza obtusa*. They have been figured in the Annual Report of the Imperial Entomologist for the last year (1936). Of these, parasite No. I, a Eulophid is most abundant and seems to exercise considerable check on the multiplication of the host in nature. Eggs are laid inside the pod on or near the host larva. The young grubs on hatching fix themselves to the body of host which is soon paralysed. The full-grown grub pupates within the pod. The adult parasite emerges in about ten to twelve days after the date of oviposition, at 27°C. This is just about one half of the period required for the development of one brood of the host under similar conditions: therefore two generations of the parasite can be completed with one of the host at this temperature. This fact indicates great potentiality of the parasite in overtaking and exercising a check on its host. In nature, however, the parasite appears rather late ; only four to seven per cent of the host larvae are parasitised during March. Parasitisation soon rises and in April as many as fifty per cent of the host larvae are affected. If the parasite could be bred artificially during winter at suitable temperature in the laboratory and brought into action in the field early in February, when the pest makes its start, very useful results may be obtained.

VII. CONTROL MEASURES

From the foregoing seasonal history of the pest it would be clear that there are two peaks in the curve of the breeding activity of the pest in nature ; the first, during October-November (autumn) which is not very important and the second during February, March and April (spring) when maximum damage to pods takes place. The weakest point in the life-history of this insect is the winter intervening the two periods of activity. In December and January the pest is reduced to its minimum and is present only in advanced larval and pupal stages inside the pods. As already stated even ninety-five per cent of these pupae succumb to the influence of winter cold and the remaining five per cent form the only source of the future infestation. The affected pods can be readily distinguished by their twisted nature and the presence of a hole for the emergence of the future fly. If all these pods are systematically collected and destroyed—and there are not many mature pods on the plants at this time—the attack in the ensuing spring may be effectively reduced.

VIII. ACKNOWLEDGMENTS

The work was carried out at Pusa during the spring of 1936 and completed at New Delhi after the shift of the Imperial Agricultural Research Institute to this place. I am indebted to Dr. H. S. Pruthi, Imperial Entomologist for rendering me advice during the course of this work and giving me all facilities by placing Pusa collection and records at my disposal and allowing me the assistance of a number of fieldmen, of whom I must particularly thank Mr. Mohd. Shafi. The coloured drawings were prepared under my supervision by Mr. P. Narayanan, Artist, whose help I acknowledge with thanks.

IX. SUMMARY

The so-called *Tur*-pod fly or Red-gram Agromyza, discovered as a pest of *Cajanus Cajan* before 1906, but not identified so far, has been determined as *Agromyza obtusa* Mall. It is an important pest of *tur* crop, causing large aggregate damage. In severe cases as much as sixty per cent of the grains may be damaged.

The eggs are laid in young pods, one with each puncture. The maximum number laid by one female is seventy-nine. They hatch in about three days at a constant temperature of 27°C. as well as at room temperature (23°-28°C.) during March-April. The larval period under these conditions lasts six to nine days. The full-grown larva pupates inside the pod and the adult fly emerges therefrom in eight to nine days. The adult flies are short-lived. With honey supplied as food they live five to six days at 27°C. and about twelve days (maximum twenty days) at 18°C. Thus, during March and April one brood of the pest is completed in about three weeks. The pest occurs on *Cajanus Cajan* from October to April. During the intervening winter its infestation is reduced to a minimum. This is the critical period when collection and destruction of affected pods can be carried out with great advantage and minimum labour.

A chalcid larval parasite of this pest has been investigated which is yet awaiting identification.

REFERENCES

Andrews, E. A. (1918). *Quart. J. Ind. Tea. Assoc.*, p. 34.

23 : 45 Curran, C. H. (1934). 'North American Diptera', p. 332.

23 : 69 Fletcher, T. B. (1914). 'Some South Ind. Insects', p. 357.

——— (1919). *Rep. Proc. Third Ent. Meeting (Pusa)*, p. 47-48.

Howlett, F. M. (1909). 'Ind. Insect Life', p. 622.

Lefroy, H. M. (1906). 'Ind. Insect Pests', p. 142-143.

Mallock, J. R. (1914). *Annales Historico-naturales Musei Nationalis Hungarici* **12**, 323-324.

: 529 Pruthi, H. S. (1936). *Report of the Imperial Entomologist, New Delhi, 1935-36*, p. 130-131.

Richhellc, A. (1928). *Boll. lab. Zool. Porticii.* **22**, 81-147.

Schroff, K. D. (1919). *Rep. Proc. Third Ent. Meeting (Pusa)*, p. 344.

STUDIES IN THE PRESERVATION OF FRUIT JUICES

I. SOME OBSERVATIONS ON THE PREPARATION AND PRESERVATION OF CITRUS FRUIT SQUASHES

BY
LAL SINGH, B.Sc. (Hons.), M.Sc. (Calif.)
Fruit Specialist, Punjab, Lyallpur
AND
GIRDHARI LAL, Ph.D. (Lond.), D.I.C.
Assistant Fruit Biochemist, Lyallpur

(Received for publication on 7th May 1937)

(With Plate VI)

I. Introduction

With the recent development of fruit farming in the Punjab, it is now recognised that this industry—citrus fruit industry in particular—is one of the future leading industries of this province. At the moment it is not possible to give exact figures to represent the tonnage of citrus fruits available in the Punjab markets, but it is certain that large quantities of citrus fruits of all kinds—*galgals* (*Citrus limonia* var. *galgal*) in particular—go to waste, for a variety of reasons, in the Pathankot-Kangra tract each year. This fruit when converted into more stable and permanent products, like squashes, cordials, essential oils, etc., should yield satisfactory profits both to the grower and manufacturer.

Fruit growers all over the province, due to lack of proper marketing organisation and transport facilities, are not able to dispose of even their good fruit at very remunerative prices. There is also a fair proportion of fresh fruit which is practically unsaleable on account of its size and condition, *viz.* ' undersized ', ' malformed ', ' blemished ', cull fruit. All this coupled with recent invasion of the Indian market by citrus fruits from California, South Africa, Italy, etc., renders the problem of profitable disposal of fresh indigenous fruits more acute. This problem will become acuter still when large acreage of citrus recently planted in the province come into bearing. It is, therefore, believed that fruit juices, squashes, concentrates and cordials (the present investigation is confined to squashes alone, a study of concentrates still being a matter of further investigation), for which there is already a good deal of demand in the Indian market, will afford a promising outlet for much of the surplus fruit.

Citrus fruit juices are rich in vitamin C, the anti-scorbutic vitamin, and vitamin A valuable for growing children, in combating colds, influenza, etc. They have additional therapeutic recommendations—citric acid preserves the alkaline balance of the blood. Hence the dietetic value of these real fruit juice beverages represents the chief advantage over similarly named synthetic products which are being produced in such large quantities by the aerated water factories in this country. It should be possible for the bottlers of synthetic carbonated beverages to successfully place in the market a line of real fruit beverages by replacing synthetic constituents by fruit juices, concentrates, etc. This would incidentally give impetus to the sugar industry, as sugar will replace the large quantity of saccharine used at present.

It would seem evident that some form of publicity, in which the dietetic importance of such beverages will have special prominence, will be a necessary preliminary to their widespread consumption.

Citrus juices can be dispensed in the following manner [Cruess, 1932].

1. Fresh juice—served direct from the extractor.
2. Canned juice—natural juice canned immediately after extraction.
3. Sweetened juices—squashes and cordials.
4. Carbonated bottled.
5. Concentrates.

With the abundance of citrus crop—particularly oranges—dispensing stands for fresh orange juice have lately come into existence in the larger towns in India and the demand for fresh juice is certainly increasing ; but the demand for such fruit beverages is more acute in summer months when practically no fresh citrus fruits except sour limes (*kagzi nimboo*) are available. Hence the need for preserved sweetened juices (ready-made for service) like squashes and cordials can hardly be over-emphasized.

Very limited literature on the subject is available in this country [Bannerjee and Rao, 1936], but a good deal of work has been done in the preservation of pure and sweetened citrus juices elsewhere [Cruess, 1914, 1920, 1932 ; Cruess and Irish, 1923 ; Irish, 1928 ; Potter, 1934 ; Traub *et al.*, 1933 ; Joslyn and Marsh, 1934]. Since the actual commercial preparation of these beverages are more or less trade secrets of the manufacturers, an attempt has been made to contribute some data on the preparation and preservation of citrus fruit squashes. Method of their preparation has been standardized and satisfactory recipes have been evolved ; the behaviour of these beverages treated with different preservatives during storage at room temperature has been studied ; and their cost of production worked out. Data collected have been given in Tables I-X (Tables I, II and X are given in the text, whereas Tables III-IX are given in the appendix).

II. Material

A fruit juice squash consists essentially of strained juice (with fine suspension of pulp) of a particular fruit to which a quantity of cane sugar is added. This is either Pasteurized or chemically preserved. It is consumed after appropriate dilution (according to taste) with plain or soda water. Due to the variation in taste, flavour, and composition, juices of all varieties of fruits are not suitable for preserving purposes [Traub *et al.*, 1933 ; Joslyn and Marsh, 1934], hence a few of the varieties grown at Government Experimental Garden, Lyallpur for trial purposes were analysed (Table I). Fully matured fruits were used.

TABLE I

Analyses of citrus fruits (December 1934)

Serial No.	Fruit and variety	Locality	Percentage of juice on fresh wt.	Balling degree of juice at 63° F.	Acidity per cent as citric acid	Ratio $\frac{\text{Balling}^\circ}{\text{Acid}}$	*p*H value	Total sugar as dextrose	Reducing sugar as dextrose	Sucrose by difference	Remarks
1	Common Malta orange.	Government Experimental Garden, Lyallpur.	46·0	11·1	0·85	13·0	4·06	7·09	3·68	3·41	Good, slightly sharp, full flavour.
2	Musambi orange .	Do. .	42·5	10·3	0·51	19·6	...	6·56	4·59	1·79	Sweet, rather flat taste.
3	Vanielle orange .	Do. .	41·3	10·5	0·78	13·5	...	6·56	3·50	3·06	Sweet, good flavour.
4	Jaffa orange . .	Do. .	41·9	9·3	0·66	14·1	...	5·85	2·87	2·98	Medium flavour.
5	Excellencis orange .	Do. .	44·2	9·6	0·73	13·1	...	6·45	3·47	2·98	Good sugar-acid blend and flavour.
6	Washington Navel .	Do. .	47·9	9·0	0·63	14·3	...	6·33	4·00	2·33	Insipid, rather flat.
7	Eureka lemon .	Do. .	45·3	8·5	4·01	2·6	3·04	...	0·86	...	Good flavour.
8	European lemon .	Do. .	46·5	8·7	5·09	1·7	2·85	...	0 88	...	Do.
9	*Galgal* (*Citrus limonia* var. *galgal*).	Pathankot .	24·1	9·5	6·11	1·5	...	...	...	...	Lacks lemon flavour.
10	Sour lime (*kagzi nimboo*).	Lyallpur .	48·9	9·4	6·9	1·4	...	...	...	...	Full lime flavour.

It will be seen from Table I that most of the varieties of oranges (Malta) are satisfactory in regard to flavour and taste of the juice, but since the variety known as common Malta is very widely grown all over the province, the experiments described in the sequel were confined only to this variety. Other varieties of Malta are being supplied by the department for propagation and when sufficient acreage comes into bearing, it would then be profitable to conduct researches on the preservation of juices and squashes of these varieties.

In order to ensure uniformity in the finished product, thirteen trees of common Malta orange were reserved in an orchard near Lyallpur. A composite sample of oranges was picked periodically from these trees and used for experiments carried out in winter 1934-35 (Table V). For experiments on orange squash (winter 1935-36, Table VII) and lemon squash (winter 1934-35 and 1935-36, Tables III and VIII respectively) fruits were periodically picked from trees reserved in Government Experimental Garden at Lyallpur. For experiments on *galgal* squash (winter 1935-36, Table VIII), fruit was obtained in one lot from Pathankot.

Cruess [1936], and Joslyn and Marsh [1934] have shown that ripeness of fruit at picking is the controlling factor in the development of a bitter taste in stored orange juice, and that the bitter taste decreased with the increase in maturity. They further found that juice from fruits picked at the end of season although not bitter, lacked in orange flavour and aroma. Hence in all the experiments described in the sequel, fully mature fruits—only those from the middle of the picking season—were employed. The early fruit was not used as its sugar-acid ratio is not sufficiently high, and the juice at the end of the crop is liable to fermentation and was not used for this reason.

III. EXPERIMENTAL

In order to prepare a standard product with suitable sugar-acid blend, a number of bottled citrus fruit squashes of different brands available in the market were obtained and analysed (Table II). These analyses show that lemon squash and orange squash contain on an average about 2·4 and 2·0 per cent acidity (in terms of citric acid), respectively, and that these could be roughly grouped in three different concentrations of sugar, *viz.*, 35°, 45° and 65° balling. In preparing these squashes, therefore, the above standard of acidity and sugar (35° B, 45° B and 65° B) was maintained.

TABLE II

Analyses of different samples of lemon and orange squashes (Bottled product of different manufacturers) as obtainable in the local market (November-December, 1934)

Serial No.	Name of brand	Balling degree at 63° F.	Percentage acidity in terms of citric acid	*p*H value of the squash	Total sugar content as glucose	Refractive index at 20°C.	Remarks
			Lemon squash				
1	Scheweppes . .	38·20	2·62	2·84	38·74	1·4000	
2	Kiora . . .	43·20	2·98	2·56	43·95	1·4079	
3	Idris	37·00	2·40	2·64	37·41	1·3973	
4	Dawe's . . .	37·90	2·27	2·75	...	1·3997	
5	Rose's . . .	37·13	2·93	2·68	36·71	1·3978	
6	Natural Southampton .	39·43	1·66	2·95	42·99	1·4032	
7	Patterson's (Lahore) .	50·03	1·07	3·04	51·32	1·4230	Pronounced artificial essential oil flavour.
8	'Kissan' Indian Mildura Farm, Montgomery.	33·03	3·14	3·07	32·03	1·3894	Peel oil flavour.
9	Valencia P. P. Products, Lahore.	38·53	3·17	3·22	39·20	1·4005	Do.
			Orange squash				
1	Rose's . . .	39·53	1·83	3·0	41·88	1·4037	
2	Jaffa Palestine . .	68·50	1·47	4·03	...	1·4662	
3	Idris	30·83	1·89	3·14	31·12	1·3873	
4	Dawe's . . .	39·13	1·28	3·37	42·61	1·4040	
5	Kiora . . .	44·63	2·24	3·34	45·12	1·4116	
6	Scheweppes . .	39·23	2·14	3·53	40·33	1·4026	
7	"Kissan" Indian Mildura Farm.	35·83	2·34	3·38	36·33	1·3948	Peel oil flavour.
8	Valencia P. P. Products, Lahore.	45·53	2·24	3·55	48·03	1·4130	Do.
9	Patterson, Lahore .	49·33	0·93	3·14	...	1·4223	Pronounced artificial essential oil flavour.

Citrus fruit squashes are prepared, usually, by mixing appropriate amounts of freshly expressed strained juice and sugar syrup. The juice is 'flash-Pasteurized' at 180°-185° F. for a few seconds and then mixed with the hot sugar syrup [Cruess, 1924]. The acidity of the finished product is standardized in accordance with the taste of consumers of a particular country. The finished product with the desired preservative is poured in bottles which have been previously sterilized in boiling water, juice sacs are added and the bottles are sealed air-tight. By preliminary small-lot experiments in this laboratory, it was found that the taste and flavour of the product obtained by mixing the juice and the syrup while hot was markedly impaired, whereas the juice and the syrup while mixed in cold, yielded a product which retained a nice, fresh, fruity flavour. This is in confirmation with the results of researches of Charley [1934] on strawberry and raspberry juices. Therefore, in the experiments described below cold mixing method was adopted, except for the product with high sugar content (say 65°B or so) when the product was slightly heated (120°F.) to dissolve the sugar.

The juice was extracted either by cutting the fruits (oranges and lemons) into halves and spindling them (with a slight pressure of the hand) on a rotating aluminium or porcelain grooved cone (peel oil practically excluded) or pressing the sliced fruit, including the entire peel (peel oil included) in an ordinary basket type press.

It is claimed by Cruess [1924] that pre-heating of the orange juice destroys the oxidase responsible for changes in flavour of orange syrup during storage. Joslyn and Marsh [1934] suggest that, in order to destroy pectic enzymes involved in clearing and clumping of the juice, it must be heated for two minutes at 87·5° C. or for eight minutes at 85° C. It is further stated by these authors [Joslyn and Marsh, 1934 ; Cruess, 1936] that removal of the dissolved air (de-aeration) which is responsible for oxidising the juice packed in the usual manner, would improve the quality of the juice. Due to lack of time and facilities these aspects of the problem could not be undertaken and are yet a matter of further investigation.

In winter 1934-35 fourteen different lots of lemon (European variety) squash (Table III), and eighteen different lots of orange squash (Table V) from the juice (with or without peel oil) of oranges (Malta) were prepared. Squashes with varying concentrations of sugar (about 35°B, 45°B and 65°B) were separately preserved with sodium benzoate, sulphur dioxide (either in the form of sulphurous acid or potassium meta-bisulphite) and Pasteurisation at 175°-180° F. for half an hour. In winter 1935-36 orange squash (Table VII), lemon squash (Table VIII) and *galgal* squash (Table VIII) with varying concentrations of sugar were preserved with potassium metabisulphite alone. In order to improve the flavour, sets containing varying amounts of thoroughly ground and strained peel emulsion were prepared (Tables VII and VIII).

The palatability of earlier samples of orange squash prepared from natural juice (acidity 0·85 per cent, Table I) suffered on account of low acidity in the finished product, whereas samples of squash prepared from natural juice of limes, lemons and *galgals* (acidity 4·0 to 7·0 per cent, Table I) were too sharp and sour on account of high acidity in the finished beverage. Acidity of the product being the factor responsible for the briskness of the beverage and thus responsible to a large extent for the thirst-quenching and attractive features of the diluted beverage, is most important. Hence the necessity of regulating the acidity to a definite standard is highly desirable so that the diluted beverage (ready for drinking) contains at least 0·4 to 0·6 per cent of acid [Charley, 1936].

In orange squash, therefore, the acidity of the finished product was raised to about 2·0 per cent in terms of citric acid (in accordance with the analysis in Table II) by the addition of calculated amounts of citric acid or lemon juice (Table V), as the natural juice of fully ripe oranges had low acidity of 0·85 per cent (Table I). In limes, lemons, and *galgals* (acidity 4·0 to 7·0 per cent, Table I), the acidity was reduced to about 2·4 per cent (in accordance with the analysis, Table II) in the finished product by adding appropriate amounts of sugar syrup. These squashes when properly diluted for drinking, gave beverage with 0·4 to 0·8 per cent acid.

All these sets were stored at room temperature and cut-outs on these were carried out at varying intervals (Tables III, V, VII and VIII).

Cut-out technique.—Changes in the taste and flavour, odour, and liquid in the canned orange juice are described as fresh, stale, bitter, off-flavour, flat, cooked, clear, clumpy, etc., in the literature as reported by Joslyn and Marsh [1934]. An attempt has been made to apply these terms in the case of squashes for determining the quality of the finished product. As a rule, results presented are based on the observations of two or more individuals. Besides observing the condition of the bottled product with regard to its taste, flavour, odour and liquid, each individual observer determined the relative merits of the product from the following score card :

Taste and flavour	10
Odour	5
Liquid	5

In each cut-out, appropriate quantities of squashes with different concentrations of sugar were diluted with the desired amount of water required to obtain an almost constant sugar-acid blend in the diluted beverage, the temperature of which was maintained at 20°C. After every test the samples were arranged in order of superiority (Tables IV and VI).

IV. OBSERVATIONS ON SQUASHES DURING STORAGE AT ROOM TEMPERATURE

1. Taste and flavour as affected by :—

(*a*) Sugar content.
(*b*) Peel oil.
(*c*) Methods of preservation.

(*a*) *Sugar content.*—The remarks tabulated in columns 'taste, flavour and odour' in Tables III, V, VII and VIII are sufficient to indicate the salient features of various sets of squashes. It will be seen from these remarks that, in general, sets of orange and lemon squash with high sugar content (65° Balling) retain their fresh-fruit character and stability to a remarkable degree, whereas in lower concentrations of sugar (35° and 45°B) the taste and flavour are adversely affected. This is supported by Cruess and Irish [1923]. This indication, that high sugar content helps to arrest the deterioration in flavour and taste of the bottled juices, is also confirmed by Charley [1936].

(*b*) *Peel oil.*—To improve the flavour of the bottled squashes, preliminary experiments conducted in this laboratory by using artificial orange and lemon essences, indicated that using small doses of these essences (four to six drops per 24-oz. bottle) did not appreciably improve the flavour, whereas larger doses (ten to fifteen drops per 24-ozs. bottle) imparted a definite artificial flavour to the product which was rather undesirable. Experiments to test the effect of orange oil on the keeping qualities, flavour, etc., of natural orange juice are mentioned in literature [Joslyn and Marsh, 1934]. Preliminary trials by adding fresh 'cold-pressed' orange oil, indicated that even a minute quantity of this oil, due to the presence of terpenes, imparted a 'terpeney' odour to the bottled squashes even after two months' storage. Due to the inability of getting terpeneless orange and lemon oils, these experiments could not be continued further. In winter 1934-35 (Table V) sets of orange squash with varying concentrations of sugar (35°, 45°, 65°B) were prepared in which orange juice including peel oil from the entire fruit (sliced and pressed in a basket press) was used. Samples of squash with low sugar content (35° and 45°B) developed an unpleasant bitter taste and with ageing of the squash a peculiar and undesirable terpenous odour was imparted to the bottled product, hence 'cut-outs' on these sets were discontinued after four months' storage. On the contrary, squash with high sugar content (65°B) gave satisfactory results (Table V, lots 16-18); bitterness of the peel appeared to be masked by the sweetness of the heavy syrup, but very slight terpenous effect still remained in the product. In winter 1935-36, therefore, further experiments by using varying amounts of peel emulsion in the squash (35°, 45°, 65°B) were conducted. The results are presented in Tables VII and VIII.

It is seen that emulsion of peel of two to four per cent of fruits used for extraction of the juice gave a satisfactory product, which had a marked orange flavour even after one year's storage. Emulsion was obtained by thoroughly grinding the peel and squeezing out the same through a thick cloth in the squash. These sets are still under observation.

(*c*) *Methods of preservation.*—Preservation by Pasteurization and the use of sodium benzoate and sulphur dioxide (as potassium meta-bisulphite or sulphurous acid) were compared. The 'cut-out' results were recorded with the aid of score card system (page 83) and the samples were arranged in order of superiority (Tables IV and VI). A study of these tables will show that preservation by sulphur dioxide (as 6·0 per cent solution of sulphurous acid or potassium meta-bisulphite) yielded the best product.

Regulations in England and America [Cox, 1926] permit the use of either benzoic acid or sulphurous acid for juices and squashes. The results tabulated in Tables III, IV, V and VI clearly indicate that preservation by sulphur dioxide yielded a product superior in taste, flavour, odour and appearance (colour) to those preserved either with sodium benzoate (confirming Potter's [1934] observations) or Pasteurization. Sodium benzoate even in the purest form imparted a peculiar 'chemical' odour resembling iodoform and a 'burning' taste to the product (confirming the results of Cruess and Irish [1923]), whereas Pasteurized sets developed an unpleasant 'cooked' flavour which was definitely noticeable to expert taste. 'Cooked' flavour was more pronounced in squashes with low sugar density (35°B and 45°B). Sulphur dioxide in the freshly prepared product imparted a slight sulphurous odour and taste to the product which was not discernible when the product was diluted to an appropriate degree for drinking purposes. This adverse taste and odour of the bottled product, however, disappeared in about nine months' storage (Tables III and V).

With a view to see how long a product remained fit for consumption after it has once been opened, the product bottled under different methods of preservation, after cut-out tests, was resealed and occasionally opened and recorked in the laboratory during summer months. Pasteurized sets spoiled within three or four days, whereas chemically preserved sets showed no signs of infection even when kept in this condition for over two months.

From the above observations it would seem that sulphur dioxide should be used in preference to benzoic acid or Pasteurization for preserving fruit juices and squashes. Potter [1934], while comparing preservation by sulphur dioxide and sodium benzoate, recommends the use of sulphur dioxide for preserving fruit juices and squashes and also states, "It has also been found that palatability of fruit juice, notably lemon juice preserved with sulphur dioxide, is superior to juice preserved with benzoic acid".

An experiment, conducted in winter 1935-36, indicated that the maximum permitted concentration of sulphur dioxide (350 p.p.m.) could be fairly diminished (say 100-200 p.p.m.) in squashes with high sugar concentration (65°B). It is known that sugar syrup in such high concentration has an effective preservative action, but to improve the keeping quality of the product after it has been opened once during summer months, in this country, the use of 100-200 p.p.m. of sulphur dioxide was found to be quite a good safe-guard against the spoilage of the opened product. These observations have yet to be confirmed with systematic inoculation experiments.

2. *Colour changes*

Next in importance to taste and flavour is the colour of the prepared citrus fruit squashes. Freshly prepared orange squash is a light yellow, cloudy liquid, whereas lemon squash is a pale yellowish white, cloudy liquid. Colour changes in these squashes, as observed at varying intervals in different sets of orange and lemon squashes are detailed in Tables III and V. It will be seen from these tables that irrespective of sugar concentration, colour of the Pasteurized sets and those preserved with sodium benzoate, changed gradually from light yellow to deep orange during about 1¼ years' storage, whereas colour of the sets preserved with sulphurous acid or potassium meta-bisulphite underwent very little change. It appears, therefore, that the bleaching action of sulphur dioxide retards the colour changes effectively. This is in concurrence with the results reported in *Food Manufacture* [1933], where it is also stated that for this reason sulphur dioxide should be employed as preserving agent in preference to benzoic acid. Rate of colour changes (yellow to deep brown) was more rapid and intense in orange squash containing peel oil than that without peel oil (Table V, sets 16 and 18). Original colour of sets 16 and 18 (Table V) was markedly yellow which, as stated by Traub *et al.* [1933] and Camp *et al.* [1932], is due to the presence of citrus oil. These observations indicate that the presence of oil when the fruit juice squash is not preserved with sulphur dioxide, augments the adverse colour change.

Browning and ultimately darkening of product is a serious matter in the case of bottled juices or squashes. It is believed by Cruess [1932] and also stated in *Food Manufacture* [1933] that darkening may be due, partly at least, to the formation of dark-coloured compounds between the proteins or their decomposition products—amino-acid and hexose sugars. It is further stated by Cruess [1932] that low storage temperature and exclusion of oxygen retard the change. It is also reported in literature [*Food Manufacture*, 1933] that storage at high temperature is a frequent cause of darkening, but the possible use of very hard water in making sugar syrup by hot process and consequent formation of caramelisation products should not be overlooked. In the present investigation, however, no attempt has been made to study the cause and nature of various factors affecting the colour changes ; and this aspect of the problem is still a matter of further investigation.

3. *Sediment*

The constituents of a fruit juice may essentially be divided into three classes :—(*a*) Substance in true solution, such as sugars, acids, proteins and pectins, (*b*) substance in the colloidal state, such as proteins and pectins, (*c*) large suspended particles, such as disintegrated cell-walls. The effect of storage on these phases of orange and lemon squash bottled under different methods of preservation are tabulated as cloudy, clumpy and clear in columns ' liquid ' in Tables III and V. It will be seen that in the chemically preserved orange squash of 35° and 45° balling strength, the sediment completely settled down in about three months storage, whereas Pasteurized sets remained cloudy (colloidal suspension) even after one year's storage. It appears that heating renders the colloidal suspension more resistant to decomposing into soluble products, and it is believed by Charley [1936] that this haziness or cloudiness is largely chemical in origin. On the other hand suspended matter in the chemically preserved sets (prepared from juice without peel oil) with high sugar density (65°B) rises on top near the neck of the bottle, leaving a brilliantly clear liquid below.

In the case of lemon squash, as seen from Table III, the rate of settling of sediment was slower still. In the chemically preserved sets the sediment completely separated in eight to ten months' storage, whereas Pasteurized

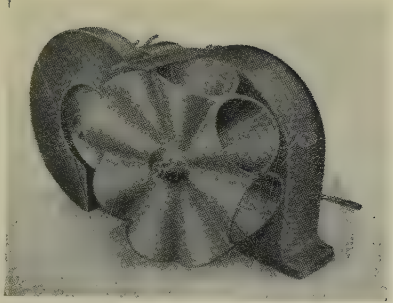


FIG. 1. Orange and lemon halving machine

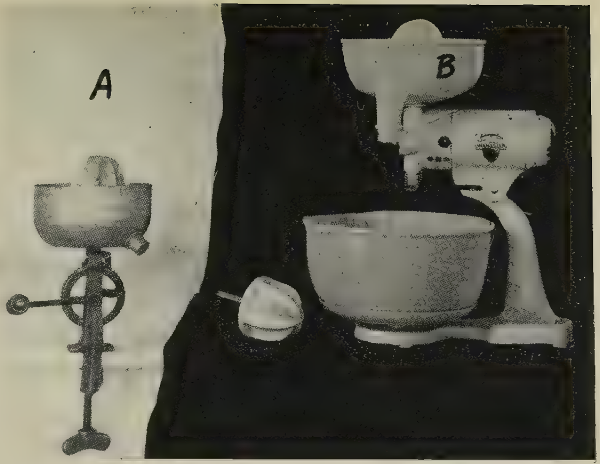


FIG. 2. (A) Hand-worked and (B) power-driven juice extractors

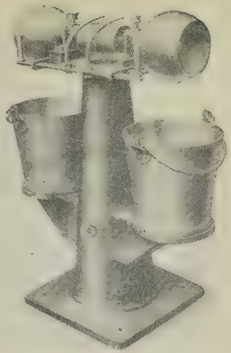


FIG. 3. Orange and lemon scooping machine

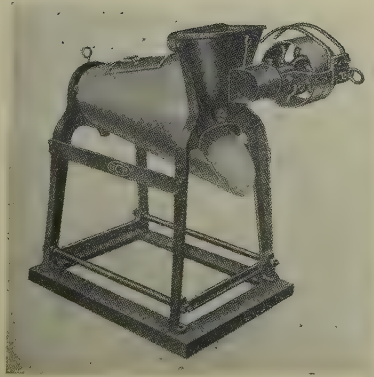


FIG. 4. Fruit pulp screening machine

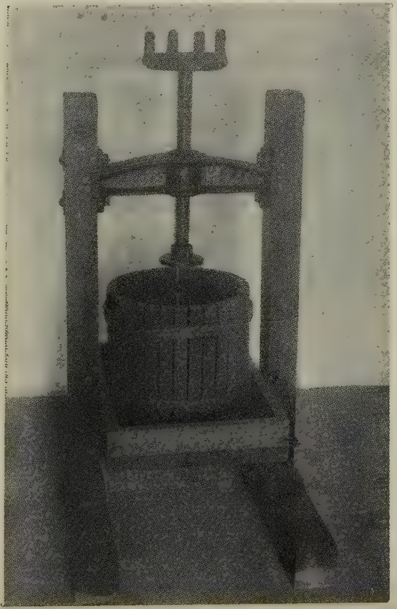


FIG. 5. Basket-type press (hand-worked)

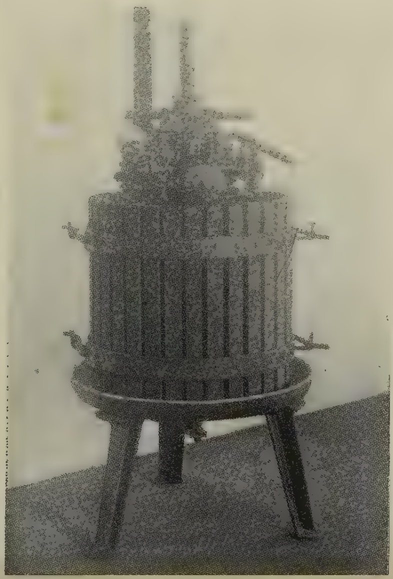


FIG. 6. Hydraulic juice press

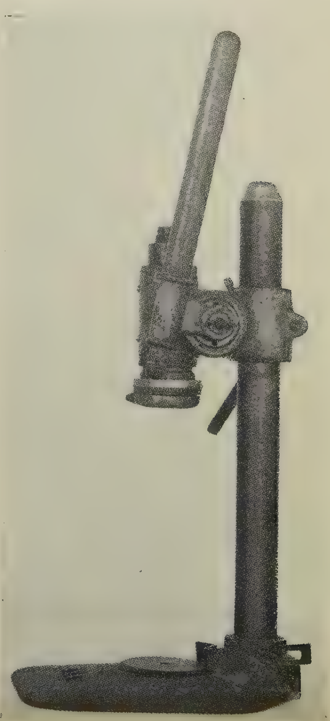


FIG. 7. Crown-capping machine

sets with low concentration of sugar (35° and 45°B) remained cloudy even after a year. Cloudiness for a longer duration in lemon squash is probably due to a high pectin content of lemon juice which resists decomposition to soluble pectinous substances.

It was also observed that in orange squash prepared from juice containing peel oil (Table V, sets 16–18) all the larger suspended particles rose on top irrespective of sugar concentration. A similar phenomenon in orange juice containing citrus oil has been observed by Traub *et al.* [1933].

Clumping which is rather unsightly in the finished product was observed in products with low sugar concentration (35° and 45°B) particularly in thirty-five per cent sugar concentration, whreas in a denser medium (65°B) no clumping was observed. In the literature on the subject [*Food Manufacture*, 1933], the addition of colloidal substances, such as gelatine or gum is recommended, but is not favoured as their addition is suggestive of adulteration. No experiments, in this connection, however, have been carried out in this laboratory so far.

V. GENERAL RECOMMENDATIONS FOR THE MANUFACTURE OF CITRUS FRUIT SQUASHES

Raw material

The fruit should be reasonably clean and all decayed and mouldy fruit must be discarded. It should be washed to remove mould spores, dust or other foreign matter adhering to the skin. It is profitable to use low grade, undersized and unattractive fruits, a considerable quantity of which do not find ready sale in the market.

Extraction of juice

The fruit (orange or lemon) is cut into halves by hand or machine (Plate VI, fig. 1) and juice is extracted by use of revolving cone extractors illustrated in Plate VI, figs. 2 (A & B) and 3. Extractors in Plate VI, fig. 2A (hand-worked) and 2B (power-driven) are suitable for work on home scale, whereas that in fig. 3 (power-driven) can be used for production on a semi-commercial scale. To remove coarse particles, seeds, etc., the juice is strained through a coarse cloth or a fine metallic stainless steel or monel metal sieve. For work on a larger scale, the use of fruit pulp screener illustrated in Plate VI, fig. 4 is recommended.

Juice from sour limes (*kagzi nimboo*) is extracted by the use of basket press (Plate VI, fig. 5), or the hydraulic press (Plate VI, fig. 6—for handling larger quantities of material). Machinery given in Plate VI, figs. 2, 5 and 6 were used for the preparation of squashes in this laboratory.

Recipes and cost of production

Recipes giving the appropriate amounts of fruit, juice, sugar, etc., required for the preparation of orange, lemon and *galgal* squash separately with a final concentration of sugar, *viz.*, 35°, 45° and 65° balling strength

(Table IX, column I), are given in Table IX, columns II-VI. The cost of production, *viz.* cost of fruit, sugar, acid, containers, labour and labelling excluding supervision charges and depreciation (Table IX, columns VII-XI) with total number of 24-oz. capacity bottles (Table IX, column XII) produced from a known amount of juice (Table IX, column III), total cost of production (Table IX, column XIII) and cost per 24-oz. capacity bottle (Table IX, column XIV), is also recorded. The number of fruits or the weight of fruit and juice as given in Table IX, columns II and III are the average figures calculated from various lots of fruits and the juice used for preparing different lots of squashes during this investigation.

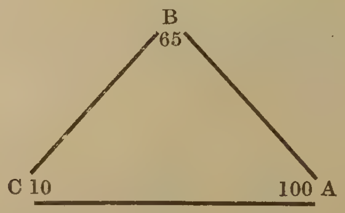
As already pointed out in Section II of this paper, a definite standard of acidity, *viz.*, about 2·0 per cent (in terms of citric acid) in orange squash (items 1 to 3, Table IX) and about 2·4 per cent in lemon and lime squash (items 4 to 8, Table IX) was maintained. In view of this, the recipes given above were calculated on the basis of the average composition of various citrus juices (Table X) during the season and the following method was adopted in regulating the strength of sugar syrup and acidity in the finished product.

TABLE X

The average composition of citrus juices during the season

Juice	Specific gravity at 20·0°C.	Balling degree at 63°F.	Percentage acidity as citric acid
Orange (common Malta)	1·038	10·0	0·80
Lemons (imported varieties and *galgal*) .	1·039	10·0	6·50
Lime (*kagzi nimboo*)	1·032	9·5	6·90

Sugar concentration of the juice was raised to the desired strength (35°, 45° or 65°) by the addition of cane sugar by the following method [Lal Singh, 1922].



A.—Concentration of sugar, 100 per cent.
B.—Desired concentration, say 65·0 per cent.
C.—Balling strength of the juice, say 10·0 per cent.

Then

A — B=weight of juice to add, *i.e.* . . . . 35 lbs.
B — C=weight of sugar to add, *i.e.* . . . . 55 „

In other words, 55 lbs. of sugar, when added to 35 lbs. of juice of 10° balling, would give a finished product with 65·0° balling strength.

Acidity of the product thus made was determined by a deci-normal solution of sodium hydroxide [Cruess and Christie, 1922]. The acidity was raised in orange squash or lowered in lemon and lime squash to the desired standard by adding calculated amounts of citric acid or sugar syrup, respectively. In orange squash, if desired, the acidity could also be raised by adding calculated amount of lemon juice in place of artificial citric acid.

It will be seen from Table IX that in preparing orange squash (about 2·0 per cent acidity in the finished product as pointed out previously) with a final sugar concentration of 35°, 45° and 65° balling, 100 lbs. of juice requires 40 lbs., 70 lbs. and 157 lbs. of sugar, and 2 lb. 5 oz., 2 lb. 10 oz. and 4 lbs. 6 oz. of citric acid, respectively. In the case of lemon squash (*galgal* variety) with about 2·4 per cent acidity in terms of citric acid (as pointed out previously) having a sugar concentration of 35°, 45° and 65° balling in the finished product, 100 lbs. of juice requires 90 lbs., 128 lbs. and 200 lbs. of sugar, and 10·5, 8·5 and 2·0 gallons of water, respectively. Similarly in lime squash (about 2·4 per cent acidity in the finished product) with a final concentration of 35° and 65° balling strength, 100 lbs. of juice require 100 lbs. and 225 lbs. of sugar, and 13·0 gallons and 2·0 gallons of water, respectively.

The appropriate proportions of juice, sugar, etc., as mentioned above are mixed in cold (squash with 65° balling strength may be heated to about 120°F. to dissolve sugar); and to remove insoluble matter which may be present in sugar, the finished product is strained through a coarse cloth. Potassium meta-bisulphite (0·02 to 0·07 per cent, the amount used being roughly inversely proportional to the syrup strength) is added. In order to improve flavour (orange and lemon squash only) two to four per cent thoroughly ground and strained peel emulsion of the fruits employed for juice extraction is added, the product is poured in bottles which have previously been sterilized in boiling water; juice sacs are added and the bottles sealed air-tight with sterilized cork wads or crown caps. In this laboratory crown top bottles were used which were sealed by a crown capping machine (Plate VI, fig. 7). For work on a larger scale, however, automatic filling, crown corking, and capsuling machines can be purchased. The bottled product after labelling is placed (sideways) in a case and stored in a cool, dry place. It was observed during storage that bottles placed in upright position developed an unsightly ring at the top of the liquid.

In connection with the experiments mentioned in the earlier part of the paper, the following number of bottles (orange, *galgal* and lime squash), collectively, were prepared.

6-oz. capacity bottles	295
12-oz. capacity bottles	1028
24-oz. capacity bottles	302

As mentioned previously recipes and the cost of production have been based on the number of bottles prepared above. The cost of the finished product (Table IX, column XIV), on account of fruit, sugar, acid, containers, labels, labour excluding supervision charges and depreciation of machinery ranges from Re. 0-4-6 to Re. 0-6-11 per 24-oz. bottle of orange squash, lemon squash and lime squash of different concentrations of sugar. Empty second-hand bottles (costing Rs. 15 to Rs. 21 per gross of 24-oz. capacity bottles or Re. 0-1-9 to Re. 0-2-4 per bottle) were used for bottling the product. The cost of production will, however, increase if new imported bottles are used, which are rather expensive.

Acknowledgments

The authors are indebted to the Imperial Council of Agricultural Research for a special scheme of research on the preservation of fruit and vegetables in the Punjab, the investigation recorded being a part of the work carried out under the scheme. The authors also wish to express their thanks to Messrs. Bal Singh, Jalmeja Singh and Abdul Aziz Khan of the Fruit Section, Lyallpur, for assistance rendered in carrying out the cut-outs during the course of this investigation.

Summary

On the basis of analysis of samples of eighteen different brands of citrus squashes available in the market, various sets of squashes of orange (Malta), lemon (imported varieties and *galgals*) with different sugar concentrations (35°, 45°, and 65° balling strength), preserved by different methods of preservation were prepared, and stored at room temperature for a period of 1¼ year. Their behaviour during storage has shown that :—

1. Citrus fruit squashes with high sugar content (65°B) retain their fresh-fruit character and stability to a marked degree.

2. Addition of thoroughly ground and strained (through a thick cloth) peel emulsion of two to four per cent fruits used for juice extraction, considerably improves the flavour and aroma of the bottled product. This phenomenon is more marked in squashes with high sugar density, whereas a slightly bitter taste (though palatable) is imparted to the product with low sugar content.

3. Preservation with sulphur dioxide yields a product superior in taste, flavour and odour to that preserved with sodium benzoate or Pasteurization. Sodium benzoate, even in the purest form, imparts a peculiar chemical odour, resembling iodoform, and a burning taste to the product, whereas Pasteurized squash develops an unpleasant cooked flavour. Sulphur dioxide imparts a slight sulphurous odour to the freshly prepared product which is not noticeable in the diluted beverage, but this adverse effect disappears in about nine months' storage at room temperature.

4. For effective preservation, maximum permitted concentration of sulphur dioxide (350 parts per million) can be fairly diminished (say 100 to

200 p. p. m.) in squashes with high sugar content. It is convenient to add sulphur dioxide in the form of potassium meta-bisulphite (a salt containing about fifty per cent sulphur dioxide).

5. Pasteurized squash, once opened during summer months, gets spoiled within three to four days, whereas the chemically preserved squash, occasionally opened and recorked in the laboratory, shows no sign of infection even when kept in this condition for over two months.

6. Sets of squash, other than those preserved with sulphur dioxide, undergo marked colour changes (light yellow to deep brown) in about $1\frac{1}{4}$ year's storage, whereas the bleaching action of sulphur dioxide seems to arrest these adverse colour changes effectively.

7. Rate of settling of sediment in the Pasteurized squash is much slower than in the chemically preserved squash, colloidal suspension (cloudiness) persists in the former even after one year's storage.

Method of preparation and strandardization of orange and lemon squash has been given, their recipes and cost of production have been worked out. Cost per 24-oz. capacity bottles (second-hand empty bottles being used), excluding supervision charges and depreciation, varies between Re. 0-4-6 and Re. 0-6-11 for different sugar densities of various squashes.

REFERENCES

Bannerjee, B. N. and Ranga Rao, N. K. (1936). *Agric. and Live-Stock in Ind.* **6**, 139.

Camp, *et al.* (1932). *Flo. Agric. Expt. Stn. Bull.* **248**.

Charley, V. L. S. (1934). *Food Manufacture* **9**, 11-16.

——————(1936). *Fruit Products J.* **16**, 36-40.

Cox, H. E. (1926). 'The Chemical Analysis of Foods'. (Appendix on preservatives in foods). P. Blackston's Sons & Co. Philadelphia.

Cruess, W. V. (1914). *Calif. Agric. Expt. Stn. Bull.* **244**

—————— (1920). *Calif. Agri. Expt. Stn. Circ. No.* **220**.

—————— (1924). 'Commercial Fruit and Vegetable Products'. (Chapters on fruit juices and syrups). Mcgraw-Hill. New York.

—————— (1932, 1). *Calif. Agric. Exten. Ser. Circ.* **65**.

—————— (1932, 2). *Food Manufacture* **7**, 363-367.

—————— (1936). *Fruit Products J.* **15**, 164-165.

Cruess, W. A. and Christie, A. W. (1922). 'Laboratory Manual of Fruit and Vegetable Products', p. 98.

Cruess, W. V. and Irish J. H. (1923). *Univ. Calif. Expt. Stn. Bull.* **359**.

'Fruit Pulp Squashes' (an article) (1933). *Food Manufacture* **8**, 261-263.

Irish, J. H. (1928). *Univ. Calif. Expt. Stn. Circ.* **313**.

Joslyn, M. A. and Marsh, G.L. (1934, 1). *Fruit Products J.* **14**, 45-50.

—————————— (1934, 2). *Ind. Eng. Chem.* **26**, 295-299.

Lal Singh (1922). 'Canning Age', p. 11.

Potter, R. S. (1934). *Food Manufacture* **9**, 126-130.

Traub, *et al.* (1933). *Plant Phys.* **8**, 35-80.

APPEN

TABLE

Cut-out tests on lemon squash (European variety) stored at

Lot No.*	Treatment (preservative)	16th April 1935			25th June	
		Flavour and taste	Odour	Liquid	Flavour and taste	Odour
1	0·10 per cent sodium benzoate	Fresh sharp .	Fresh slightly chemical.	Cloudy dirty yellow	Fresh . .	S. chemical odour.
2	0·03 per cent SO_2 as sulphurous acid (6 per cent solution)	Do. .	Sulphurous .	Cloudy light yellow	Fresh sharp s. after taste.	Sulphurous .
3	Pasteurized at 175°-180° F. for ½ hour.	Medium sharp	Fresh . .	Cloudy dirty yellow	Slightly off .	Fresh . .
4	0·10 per cent sodium benzoate	Medium slightly flat.	Fresh . .	Cloudy dirty yellow	Slightly flat .	Fairly fresh .
5	0·03 per cent SO_2 as sulphurous acid (6 per cent solution)	Fresh sharp .	Sulphurous .	Cloudy light yellow	Fresh sulphurous bad after-taste.	Sulphurous
6	Pasteurized at 175°—180°F. for ½ hour	Fresh slight after-taste.	Fairly fresh .	Cloudy dirty yellow	Slightly cooked.	Slightly off
7	0·10 per cent sodium benzoate	Fresh sharp .	Slightly off .	Do. .	Fresh chemical after-taste.	Do.
8	0·03 per cent SO_2 as sulphurous acid (6 per cent solution)	Fresh very sharp	Sulphurous .	Cloudy light yellow	Fresh bad after-taste	Slightly sulphurous
9	Pasteurized at 175°-180°F. for half an hour	Sharp medium	Fairly fresh .	Cloudy yellow	Sharp s. bitter	Fairly fresh
10	0·10 per cent sodium benzoate	Fresh sharp .	Slightly off .	Do. .	Fairly fresh .	Chemical odour
11	0·03 per cent SO_2 as sulphurous acid (6 per cent solution)	Fresh sharp .	Sulphurous .	Cloudy light yellow	Sharp slightly after-taste	Sulphurous
12	Pasteurized at 175°-180°F. for ½ hour.	Fresh . .	Fresh . .	Cloudy light orange	Fresh . .	Fairly fresh.
13	0·035 per cent. SO_2 as sulphurous acid (6 per cent solution)	Fresh slight after-taste	Fairly sulphurous	Cloudy light yellow	Fresh slight after-taste	Slightly sulphurous
14	Pasteurized at 175°-180°F. for ½ hour	Slightly cooked	Fresh . .	Cloudy dirty yellow	Very slightly cooked	Fresh . .

**Lots 1-3.* Acidity of the finished product decreased by added water to about

Lots 4-6. Acidity of the finished product decreased by added water to about 2·4

Lots 7-9. Natural lemon juice—Balling concentration increased to about 34°

Lots 10-12. Natural lemon juice—Balling concentration increased to

Lots 13-14. Natural lemon juice—Balling concentration of the juice raised to

(*Lots 7-14* were too sharp and acid since natural juice of lemons was employed

DIX

III

room temperature in January, 1935 (winter 1934-35 trials)

1935	30th October 1935			13th June 1936		
Liquid	Flavour and taste	Odour	Liquid	Flavour and taste	Odour	Liquid
Cloudy light orange	Slightly off .	Slight chemical odour	Cloudy light orange.	Off . .	Chemical odour	Clear deep orange
Cloudy light yellow	Fresh slight after-taste	Very slightly sulphurous	Clear light yellow	Fresh very slight after-taste	Fresh . .	Very clear light colour
Cloudy light orange	Slightly flat .	Slightly off .	Cloudy light orange	Flat cooked .	Off . .	Slightly cloudy deep orange
Cloudy light orange	Bad after-taste	Chemical odour	Cloudy deep orange	Bad after-taste	Chemical odour	Slightly cloudy deep orange
S. cloudy light yellow	Fresh sulphurous	Slightly sulphurous	Very clear yellow colour	Fresh . .	Fresh . .	Very clear light yellow colour
Cloudy deep yellow	Slightly flat .	Cooked .	Cloudy light orange	Cooked slightly bitter	Cooked .	Cloudy light orange colour
Cloudy orange	Off bad after-taste	Off . .	Cloudy deep orange	Off bad after-taste	Off . .	Clear light brown colour
Clear light yellow colour	Bad after-taste	Very slightly sulphurous	Very clear light yellow	Fresh . .	Fresh . .	Very clear light yellow
Cloudy light orange	Flat and s. bitter	Cooked .	Cloudy dirty orange colour	Cooked slightly bitter.	Stale . .	Cloudy deep orange
Cloudy light orange	Off chemical after-taste	Chemical odour	Clear orange colour	Off chemical after-taste	Chemical .	Clear clumpy suspension on top orange colour
Slightly cloudy light yellow	Sharp slight after-taste	Very slightly sulphurous	Clear yellow	Fresh . .	Fresh . .	Clear yellow
Cloudy dirty orange	Fairly fresh s. bitter	Fairly fresh .	Cloudy dirty orange colour	Cooked slightly bitter	Cooked .	Clumpy suspension dirty orange colour
Clear light yellow	Fresh very slight after-taste	Do. .	Clear light yellow	Fresh pleasant	Fresh . .	Clear light yellow
Cloudy light orange colour	Fresh . .	Very slightly cooked	Clear orange colour	Fresh . .	Fairly fresh .	Clear deep orange colour

2·8 per cent. Balling concentration of the juice increased to about 30° by added sugar.
per cent. Balling concentration of the juice raised to about 43° by added sugar.
by added sugar.
about 45° by added sugar.
65° by added sugar.
and no water was added to regulate the acidity.)

TABLE IV

Results of cut-out tests (Table III) carried out at different intervals during the storage period of lemon squash (winter 1934-35 trials)

(Lot numbers were placed in the following order of superiority)

Observer	Date	Lots	Order
B. S., J. S. & A. R. . . .	16th April 1935 .	(Lots 1—3)	1, 3, 2
G. L., J. S. & A. R. . . .	26th June 1935 .	,, .	2, (1 & 3)
G. L., K. C. & A. A. K. . .	30th Oct. 1935 .	,, .	2, 1, 3
G. L. & K. C.	13th June 1936 .	,, .	2, 1, 3
B. S., J. S. & A. R. . . .	16th April 1935 .	(Lots 3—5)	6, 5, 4
G. L., J. S. & A. R. . . .	26th June 1935 .	,, .	5, 6, 4
G. L., K. C. & A. A. K. . .	30th Oct. 1935 .	,, .	5, 6, 4
G. L. & K. C.	13 June 1936 .	,, .	5, 6, 4

TABLE IV—*contd.*

Results of cut-out tests (Table III) carried out at different intervals during the storage period of lemon squash (winter 1934-35 trials)—contd.

(*Lot numbers were placed in the following order of superiority*)—contd.

Observer	Date	Lots	Order
B. S., J. S. & A. R. . . .	16th April 1935 .	(Lots 7—9)	9, 7, 8
G. L., J. S. & A. R. . . .	26th June 1935 .	,, .	8, 7, 9
G. L., K. C. & A. A. K. . .	30th Oct. 1935 .	,, .	8, (9 & 7)
G. L. & K. C.	13th June 1936 .	,, .	(8 & 7), 9
B. S., J. S. & A. R. . . .	16th April 1935 .	(Lots 10—12)	12, (11 & 10)
G. L., J. S. & A. R. . . .	26th June 1935 .	,, .	12, (11 & 10)
G. L., K. C. & A. A. K.. . .	30th Oct. 1935 .	,, .	12, 11, 10
G. L. & K. C.	13th June 1936 .	,, .	11, (10 & 12)
B. S., J. S. & A. R. . . .	16th April 1935 .	(Lots 13 & 14)	(13 & 14)
G. L., J. S. & A. R. . . .	26th June 1935 .	,, .	(13 & 14)
G. L., K. C. & A. A. K. . .	30th Oct. 1935 .	,, .	13, 14
G. L. & K. C.	13th June 1936 .	,, .	13, 14

TABLE

Cut-outs† on orange (Malta) squash stored at room

Lot No.*	Treatment preservative	24th April 1935			26th June	
		Flavour and taste	Odour	Liquid	Flavour and taste	Odour
1	0·10 per cent sodium benzoate	Medium fresh	Slightly chemical	Clear light yellow	Medium fresh slight after-taste	Slightly chemical
2	0·035 per cent SO_2 as sulphurous acid (6 per cent solution)	Fresh very sharp	Sulphurous	Do.	Fresh slight after-taste	Sulphurous
3	Pasteurized at 175°-180°F. for ½ hour	Slightly cooked	Fresh	Cloudy light yellow	Slightly cooked	Fresh
4	0·10 per cent sodium benzoate	Fresh queer ter-taste	Medium fresh	Clear light yellow	Unpleasant after-taste	Medium
5	0·035 per cent SO_2 as sulphurous acid	Fresh sharp	Sulphurous	Do.	Sharp slight after-taste	Slightly sulphurous
6	Pasteurized at 175°-180°F. for ½ hour	Slightly cooked	Slightly flat	Cloudy light yellow	Medium fresh	Slightly off
7	0·10 per cent sodium benzoate	Medium fresh	Chemical	Cloudy flaky suspension yellow	Medium fresh	Chemical
8	0·035 per cent SO_2, as pot. meta-bisulphite	Fresh slight after-taste	Sulphurous	Cloudy suspension light yellow	Fresh slight after-taste	Slightly sulphurous
9	Pasteurized at 175°-180°F. for ½ hour	Slightly flat	Fairly fresh	Cloudy dirty yellow	Slightly flat	Fairly fresh
10	0·1 per cent sodium benzoate	Fresh	Peculiar chemical	Clear yellow	Medium fresh slight after-taste	Peculiar chemical
11	0·035 per cent SO_2, as pot. meta-bisulphite	Fresh	Slightly sulphurous	Clear light yellow	Fresh slight after-taste	Very slightly sulphurous
12	Pasteurized at 175°-180°F. for ½ hour	Slightly cooked	Slightly stale	Cloudy dirty yellow	Slightly cooked	Slightly stale
13	0·1 per cent sodium benzoate	Fresh	Chemical odour	Slightly cloudy dirty yellow	Medium slight after-taste	Peculiar chemical odour
14	0·035 per cent SO_2, as pot. meta-bisulphite	Fresh	Slightly sulphurous	Clear light yellow	Fresh slight after-taste	Slightly sulphurous
15	Pasteurized at 175°-180°F. for ½ hour	Slightly cooked	Slightly stale	Cloudy suspension dirty yellow	Slightly cooked	Slightly stale
16	0·10 per cent sodium benzoate	Fresh	Peculiar chemical	Clear orange colour	Medium fresh slight after-taste	Very slightly chemical
17	0·035 per cent SO_2 as pot. meta-bisulphite	Fresh slight after-taste	Fresh	Clear light yellow	Medium slight after-taste	Fresh
18	Pasteurized at 175°-180°F. for ½ hour	Fresh slight after-taste	Fairly fresh	Very clear dirty light orange	Fresh slight after-taste	Fresh

**Lots 1-3.* Spindled orange juice, natural acidity raised to about 2·2 per cent
to about 35° by

Lots 4-6. The same as above except that the balling concentration of the

Lots 7-9. Spindled orange juice, natural acidity raised to about 2·0 per cent
to about 65° by

Lots 10-12. Spindled orange juice, natural acidity raised to about 2·2 per cent
duct raised to about

Lots 13-15. The same as lots 10-12, except that the balling concentration

Lots 16-18. Orange juice including peel oil from the entire skin of the fruits
added citric acid. Balling concentration of the finished

†Samples of squash (35° & 45° balling concentration of the finished product) in which
ageing of the squash a peculiar 'terpenous' odour was imparted to the product

V

temperature in February 1935 (winter 1934-35 trials)

1935	31st October 1935			8th June 1936		
Liquid	Flavour and taste	Odour	Liquid	Flavour and taste	Odour	Liquid
Clear deep yellow	Slight after-taste	Slightly chemical	Clear orange	Slight unpleasant after-taste	Slightly chemical	Clear deep orange
Clear clumpy sediment light yellow	Slight after-taste	Slightly sulphurous	Clear light yellow	Medium fresh	Fresh pleasant	Clear light orange
Cloudy light orange	...	...	...	...	...	...
Clear deep yellow	Unpleasant after-taste	Medium flavour	Clear deep orange	Queer after-taste	Slightly chemical	Clear deep orange
Do. .	Sharp slight after-taste	Medium fresh	Clear light orange	Fresh good .	Fresh pleasant	Clear light orange attractive
Cloudy light orange	Medium fresh	Slightly off .	Cloudy deep orange	Slightly bitter after-taste	Slightly stale	Cloudy unattractive deep orange
Slightly cloudy dirty orange	Medium chemical after-taste	Chemical .	Clear light orange	Slightly chemical	Slightly chemical	Clear deep orange
Cloudy suspension light yellow	Fresh slight after-taste	Slightly sulphurous	Clear light yellow	Fresh . .	Fresh no sulphurous odour	Clear orange colour
Clear light brown	Very slightly cooked	Fairly fresh .	Clear orange colour	Fairly fresh .	Fresh . .	Clear orange colour
Clear yellow .	Chemical after-taste	Peculiar chemical	Clear light brown	Chemical after-taste	Preservative odour	Clear deep brown
Clear light yellow	Fairly fresh v. slight after-taste	Very slightly sulphurous	Clear bright yellow	Fresh pleasant	Fairly fresh .	Clear light yellow good
Cloudy light orange	Slightly cooked	Stale . .	Cloudy dirty orange	Stale cooked	Stale . .	Cloudy deep orange
Slightly cloudy yellowish orange	Unpleasant after-taste	Peculiar chemical	Clear brown	Benzoate after-taste	Peculiar chemical	Clear deep orange
Clear light yellow	Fairly fresh .	Fairly fresh v. slightly sulphurous	Clear light yellow	Fresh . .	Fairly fresh .	Clear light yellow
Cloudy suspension light orange	Slightly cooked	Slightly stale	Cloudy dirty orange	Stale cooked	Stale . .	Cloudy deep orange
Clear yellowish orange	Unpleasant after-taste	Fairly fresh .	Clear brown .	Fresh but unpleasant after-taste	Fairly fresh slightly chemical	Clear deep brown.
Clear light yellow	Fresh . .	Fresh . .	Clear light yellow	Fresh pleasant	Fresh . .	Clear light orange
Clear light orange	Fresh . .	Fresh . .	Clear brown .	Fresh . .	Fairly fresh .	Clear deep brown colour

(as citric acid) by added citric acid. Balling concentration of the finished product raised
added cane-sugar.
finished product was raised to about 45° by added cane-sugar.
(as citric acid) by added citric acid. Balling concentration of the finished product raised
added cane-sugar.
by adding appropriate amount of lemon juice. Balling concentration of the finished pro-
35° by added cane-sugar.
of the finished product was raised to about 45° by added cane-sugar.
(sliced and pressed in a basket press), natural acidity raised to about 2·0 per cent by
product raised to about 65° by cane-sugar.
juice with peel oil was employed developed an unpleasant bitter taste and with the
hence the 'cut-out' tests on these lots were discontinued after four months' storage.

TABLE VI

Results of cut-out tests (Table V) carried out at different intervals during the storage period of orange (Malta) squash (winter 1934-35 trials)

(Lot numbers were placed in the following order of superiority)

Observers	Date of observation	Lots	Order
J. S., U. S., G. L. & D. D.	24th April 1935	(Lots 1—3)	3, 1, 2
J. S., B. S. & G. L.	26th June 1935	,,	3, 2, 1
G. L. & K. C.	30th Oct. 1935	,,	2, 1, 3
G. L., A. A. K. & K. C.	8th June 1936	,,	2, 1, 3
J. S., U. S., G. L. & D. D.	24th April 1935	(Lots 4—6)	6, 4, 5
J. S., B. S. & G. L.	26th June 1935	,,	5, (4 & 6)
G. L., & K. C.	30th Oct. 1935	,,	(5 & 6), 4
G. L., A. A. K. & K. C.	8th June 1936	,,	5, (4 & 6)
J. S., U. S., G. L. & D. D.	24th April 1935	(Lots 7—9)	9, 8, 7
J. S., B. S. & G. L.	26th June 1935	,,	7, (8 & 9)
G. L. & K. C.	30th Oct. 1935	,,	8, 9, 7
G. L., A. A. K. & K. C.	8th June 1936	,,	8, (7 & 9)
B. S., D. S., G. L. & A. R.	25th April 1935	(Lots 10–12)	11, (10 & 12)
B. S., J. S. & G. L.	27th June 1935	,,	(10 & 11), 12
G. L. & K. C.	30th Oct. 1935	,,	11, 10, 12
G. L., A. A. K. & K. C.	8th June 1936	,,	11, 10, 12
B. S., D. S., G. L. & A. R.	25th April 1935	(Lots 13—15).	(14 & 15), 13
B. S., J. S. & G. L.	27th June 1935	,,	14, (13 & 15)
G. L. & K. C.	30th Oct. 1935	,,	14, (13 & 15)
G. L., A. A. K. & K. C.	8th June 1936	,,	14, 13, 15
B. S., J. S., D. S. & G. L.	1st May 1935	(Lots 16—18).	17, 16, 18
B. S., J. S., & G. L.	28th June 1935	,,	(17 & 16), 18
G. L. & K. C.	30th Oct. 1935	,,	17, (16 & 18)
G. L., A. A. K., & K. C.	8th June 1936	,,	17, (16 & 18)

TABLE VII

Cut-out tests on different lots of orange (Malta) squash (winter 1935-36 trials)

Lot No.	Date of preparation	Approx. balling strength of the finished product	Treatment of juice	1st week of June 1936			2nd week of March 1937		
				Flavour and taste	Odour	Liquid	Flavour and taste	Odour	Liquid
1	11th Feb. 1936	35°B	Spindled orange juice, 0·07 per cent pot. meta-bisulphite (or about 350 parts per million of sulphur dioxide) added as preservative. Acidity raised by added citric acid. Thoroughly ground and strained peel of 2 per cent fruit used for the extraction	Fresh	Fresh	Clear yellow colour	Medium slightly bitter	Medium	Clear light orange colour
2	Do.	,,	The same as above except that peel extract of 4 per cent fruits was added.	Fresh slightly bitter	Do.	Clear light yellow abnormal sediment.	Medium slightly bitter	Medium	Clear light orange colour
3	Do.	,,	The same as 1, except that peel extract of 6 per cent fruits was added	Fresh bitter	Do.	Do.	Medium bitter	Medium	Clear light orange
4	14th Feb. 1936.	45°	The same as lot 1	Fresh slightly bitter	Do.	Clear yellow	Fairly fresh slightly bitter	Fairly fresh	Do.
5	Do.	,,	The same as lot 2	Do.	Do.	Do.	Do.	Do.	Do.
6	Do.	,,	The same as lot 3	Do.	Do.	Do.	Bitter taste	Medium slightly terpenous	Do.
7	Do.	65°	The same as lot 1	Fresh strong very good	Fresh very strong	Do.	Fresh good	Fresh	Clear light orange solid suspension on top
8	Do.	,,	The same as lot 2	Fresh good	Do.	Do.	Fresh slightly bitter	Fresh	Do.
9	Do.	,,	The same as lot	Fresh slightly bitter.	Do.	Do.	Bitter taste	Fairly fresh slightly terpenous	Do.

TABLE VIII

Cut-out tests on different lots of lemon (European), galgal (Citrus limonia *var.* galgal) *squash (winter 1935-36 trials)*

Lot No.	Date of preparation (1936)	Approx. balling strength of the finished product	Treatment of juice, etc., for preparing squash	1st week of June 1936			1st week of March 1937		
				Flavour and taste	Odour	Liquid	Flavour and taste	Odour	Liquid
			Lemon (European variety) squash						
1	6th Feb.	45°B.	Spindled juice, acidity decreased to 2·4 per cent by adding appropriate amount of water. Thoroughly ground and strained peel of one per cent fruits used for juice extraction was added to the finished product. 0·07 per cent pot. meta-bisulphite added as preservative.	Fresh . .	Fresh good	Clear yellow sediment on top and bottom	Fresh .	Fresh .	Clear, light orange sediment on top
2	Do. .	,,	The same as lot (1) except that thoroughly ground and strained peel of 2 per cent fruits employed for juice extraction, added to the finished product.	Fresh . .	Fresh .	Clear light yellow clumpy suspension	Fresh .	Fresh .	Clear light orange sediment suspended
3	Do. .	,,	The same as lot (1) except that thoroughly ground and strained peel of 3 per cent fruits employed for juice extraction was added to the finished product	Fresh good .	Fresh good	Very clear light yellow sediment normal.	Very fresh .	Fresh good	Clear light orange.
4	Do. .	,,	The same as lot (1) except that thoroughly ground and strained peel of 4 per cent fruits was added	Fresh . .	Fresh .	Clear light yellow clumpy suspension.	Fresh .	Fresh good strong	Do.
5	Do. .	,,	The same as lot (1) except that thoroughly ground and strained peel of 12 per cent fruits was added	Fresh slightly bitter after-taste good	Fresh good	Do. .	Fresh bitter	Fresh slightly terpenous	Clear light orange suspension throughout.

Lemon (galgal) *squash*

1	8th Jan.	35°	Spindled juice, acidity decreased to about 2·4 per cent by added water. 0·07 per cent pot. meta-bisulphite used as preservative, artificial flavour added	Fairly fresh	Fairly fresh	Cloudy light yellow sediment at bottom	Fairly fresh	Fairly fresh	Clear light orange.
2	10th Jan	,,	Fruits with ½ peel pressed in a basket press. The rest of the treatment is the same as lot (1)	Fairly fresh very bitter	Fresh	Slightly cloudy deep yellow	Fresh very bitter	Fresh slightly terpenous	Do.
3	17th Dec.	45°	The same as lot (1)	Fresh	Slightly off	Cloudy yellow colour	Fresh	Fairly fresh	Do.
4	17th Dec. and 8th Jan.	,,	The same as lot (2)	Fairly fresh	Do.	Do.	Fairly fresh	Slightly flat, s. terpenous	Do.
5	7th Jan. and 18th Dec.	65°	The same as lot (1)	Fresh rather sweet	Do.	Clear clumpy suspension yellow	Fresh	Slightly off	Do.
6	10th Jan.	,,	The same as lot (2)	Fresh very slight bitterness	Fresh	Clear yellow clumpy sed. on top	Fresh bitter	Slightly flat terpenous flavour	Do.

TABLE IX

Appropriate amount of juice, sugar, etc., used for the preparation of orange, lemon and galgal *squash of varying concentrations of sugar*

Serial No.	Recipes						Cost of production							
	I Approx. balling strength of the finished product	II No. of fruits or weight of fruits	III Weight of juice	IV Weight of sugar	V Weight of acid used	VI Water added to reduce the acidity in lemon and lime products	VII Cost of fruit	VIII Cost of sugar	IX Cost of acid	X Cost of containers	XI Cost of labour, labels, etc., (excluding supervision charges and depreciation)	XII Total No. of bottles 24-oz. capacity	XIII Total cost	XIV Cost per 24-oz. bottle
			Lbs.	Lb. oz.	Lb. oz.	Gallons	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.		Rs. A. P.	Rs. A. P.
							Orange squash							
1	35°	700 fruits	100	40 0	2 5	...	10 8 0	5 0 0	1 5 0	11 0 0	2 8 0	76	30 5 0	0 6 5
2	45°	"	"	70 0	2 10	...	10 8 0	8 12 0	1 10 0	12 8 0	2 8 0	86	35 14 0	0 6 3
3	65°	"	"	157 0	4 6	...	10 8 0	19 6 0	2 6 0	17 15 0	3 4 0	123	53 7 0	0 6 11
						Lemon squash (galgal *and European variety lemon)*								
4	35°	5 mds. or 410 lbs.	"	90 0	...	10·5	7 8 0	11 0 0	...	22 14 0	3 4 0	157	44 10 0	0 4 6
5	45°	"	"	128 0	...	8·5	7 8 0	13 4 0	...	22 12 0	3 4 0	156	47 0 0	0 4 10
6	65°	"	"	200 0	...	2·0	7 8 0	24 0 0	...	21 14 0	3 4 0	150	56 10 0	0 5 11
							Lime (kagzi nimboo) squash							
7	35°	205 lbs.	"	100 0	...	13·0	12 8 0	12 4 0	...	25 11 0	3 8 0	176	53 15 0	0 4 10
8	65°	"	"	225 0	...	2·0	12 8 0	27 8 0	...	23 10 0	2 8 0	162	67 2 0	0 6 7

NOTICE

Translations of the following articles are available in the Library of the Imperial Council of Agricultural Research, and can be had on loan by research workers on the same conditions as translations of similar papers issued by the various Imperial Agricultural Bureaux.

1. Tung T. H. De Krul—en Kropoek—Ziekten van Tabak en de Oorzaken van hare Verbreiding. Proefstation voor Vorsten landsche Tabak. Meded. 72, 1932.
2. La Distribuzione E La Nomenclatura Die Carboni Della Canna Da Succhero E Delle Specie Affini—R. Ciferri. (From Bolletino di Studi Informazioni del R. Giardino Coloniale di Palermo. 13 : 1-7, 1933).

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Periodical Abstracts

Lists of publications and papers on Soil Science published in the Empire Overseas in—

	Price *s.*	*d.*
1933	1	0
1934	1	0
Soil Research in the British Empire published during 1935	1	0
Lists of Publications relating to Soils and Fertilisers—		
Published monthly, per annum, post free	10	0
Monthly Letters—		
Free to recipients, within the British Empire, of 'Publications relating to Soils and Fertilisers.' Subscription, outside the Empire, per annum	4	0
Recent Developments in Soil Analysis—		
Quarterly Supplement to the above publications. Separate copies each	0	6

Occasional Papers

	Price *s.*	*d.*
Technical Communications—		
34. Tropical Soils in relation to Tropical Crops	2	6
Annual Report: For the year 1934-35	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions (by the late Sir J. B. Harrison)	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1931-34	25	0

II. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL HEALTH, VETERINARY RESEARCH LABORATORY, NEW HAW, WEYBRIDGE, SURREY

Abstracting Journal

	Price *s.*	*d.*
The Veterinary Bulletin—		
1931. Vol. 1. Quarterly (1st Number, April)	7	6
Annual Subscription	20	0
Subsequent Volumes. Monthly (1st Number, January)	5	0
Annual Subscription (postage paid)	40	0

	Price	
	s.	d.

Indexing Publication

Index Veterinarius—Four issues a year. First issue April 1933—		
Annual Subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed	100	0

III. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL NUTRITION, ROWETT RESEARCH INSTITUTE, BUCKSBURN, ABERDEEN

Journal

Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)—		
Subscription per volume of 4 numbers	42	0
Per single number	13	0

Occasional Papers

Technical Communications—		
7. Wheat : Pre-eminence as a Cereal Food, Nutritive Value ; Relation to Health and Disease	1	0
Occasional Communications—		
1. The Effect of Climate on the Composition of Pasture Plants.		

IV. OBTAINABLE FROM THE IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS PLANT BREEDING INSTITUTE, SCHOOL OF AGRICULTURE, CAMBRIDGE.

Journal

Plant Breeding Abstracts—		
Quarterly. Annual Subscription	15	0
Single copies	5	0

Occasional Papers

Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932-1935. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication of the Imperial Bureaux of Plant Genetics)	10	0
Bibliographical Monographs—		
The Experimental Production of Haploids and Polyploids	5	0
Breeding Resistant Varieties, 1930-33 (Supplement)	2	0
An Outline of Cytological Technique for Plant Breeders	1	6

V. OBTAINABLE FROM THE IMPERIAL BUREAU OF PASTURES AND FORAGE CROPS, WELSH PLANT BREEDING STATION, AGRICULTURAL BUILDINGS, ALEXANDRA ROAD, ABERYSTWYTH, WALES

Journals

	Price s.	d.
Herbage Abstracts—		
Quarterly. Annual Subscription	15	0
Single numbers	5	0
Herbage Reviews—		
Subscription is at present—Vol. 1 (1933), Vol. 2 (1934), Vol. 3 (1935), Vol. 4 (1936)—included in that to Herbage Abstracts		

Occasional Papers

	s.	d.
Bulletins—		
19. Production of Grass Seed	5	0
20. Insects and Other Pests Injurious to the Production of Seed in Herbage and Forage Crops, H. F. Barnes	2	6
21. The Influence of Climatic Conditions on Type Composition. Nils Sylvén	1	0
22. Technique of Grass Seed Production at Welsh Plant Breeding Station. Gwilym Evans	5	0
23. Production of Legume Seed	5	0
24. Collection of Native Grass Seed in the Great Plains U. S. A. F. J. Crider and M. M. Hoover	2	0

VI. OBTAINABLE FROM THE IMPERIAL BUREAU OF HORTICULTURE AND PLANTATION CROPS, EAST MALLING RESEARCH STATION, EAST MALLING, KENT

Journal

	s.	d.
Horticultural Abstracts—		
A quarterly abstract publication of current horticultural literature—		
Annual Subscription	15	0
Single copy	4	0

Technical Communications

	s.	d.
8. Horticultural Aspects of Woolly Aphis Control together with a Survey of the Literature. R. M. Greenslade	2	6

Occasional Papers

	s.	d.
3. Annotated Bibliography on Bitter-Pit. 1934	1	6
Other Publications—		
Index to Volumes I—X of the *Journal of Pomology and Horticultural Science*, 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science*. Available from the Bureau	5	0
Old and New Standpoints on Senile Degeneration, 1931. By A. P. C. Bijhouwer	0	6

VII. Obtainable from the Imperial Bureau of Animal Breeding and Genetics Institute of Animal Genetics, University of Edinburgh, King's Buildings, West Mains Road, Edinburgh

Journal

	Price s.	d.
Animal Breeding Abstracts (Quarterly). Commencing April, 1933. Annual Subscription	15	0

Occasional Papers

	s.	d.
Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0

VIII. Obtainable from the Imperial Bureau of Agricultural Parasitology, Helminthology Institute of Agricultural Parasitology, Winches Farm Drive, Hatfield Road, St. Albans, Herts

Journals

	s.	d.
Bibliography of Helminthology. For the year 1933—		
Library edition, bound in cloth	10	6
Stiff paper cover only	8	0
Helminthological Abstracts. (Issued in five or six parts per volume, each volume covering the literature of a single year.) Subscription per volume, payable in advance	30	0
Completed volumes bound in cloth	32	0

Occasional Papers

	s.	d.
The Effects of some Natural Factors on the Second Ecdysis of Nematode Infective Larvae. By G. Lapage. 25 pp.	4	0
Notes and Memoranda—		
11. Recent Developments in the Control of *Heterodera marioni*. 6 pp	1	6

Publications issued by the Imperial Institute of Entomology, 41, Queen's Gate, London, S. W. 7

	s.	d.
Bulletin of Entomological Research.—Published quarterly and containing original articles on Economic Entomology. Issued post-free. Annual subscription (payable in advance)	30	0

Review of Applied Entomology.—Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series. Series ‘A’ dealing with insect and other arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin, Series ‘B’ dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post-free.

	Series ‘A’ *s.*	Series ‘B’ *s.*
Annual subscription (payable in advance)	30	15
Vol. XXIII (1935)	42	21

Zoological Record—Part Insecta.—Published annually about July in each year and containing as complete a record as possible of the literature of the previous year chiefly from the systematic standpoint.

	Price. *s.*	*d.*
Annual subscription (including postage)	15	6
Report of the Fourth Imperial Entomological Conference, 19—27th September 1935	4	0

PUBLICATIONS OBTAINABLE FROM THE IMPERIAL MYCOLOGICAL INSTITUTE, KEW SURREY

Journal

	s.	*d.*
Review of Applied Mycology.—Annual subscription, 12 monthly parts, with title page and index (post-free)	21	0
Single part	2	0
Title page and index	3	0
Report on the Third Imperial Mycological Conference, 1934	2	0

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian postage]

1. Agriculture and Live-stock in India

ICRA. 1 A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the tropics. (Established 1931.) Published in January, March, May, July, September and November. Prepayable subscription Rs. 6 or 9*s*. 9*d*. per annum. Price per part Rs. 2 or 3*s*. 6*d*. Volumes I to VII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5 A bi-monthly scientific journal of agriculture and the allied sciences, mainly devoted to the publication of the results of original research and field experiments. (Established 1931.) Published in February, April, June, August, October and December. Prepayable subscription Rs. 15 or 24*s*. per annum. Price per part Rs. 3 or 5*s*. 3*d*. Volumes I to VII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6 A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931.) Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s*. 9*d*. Price per part Rs. 2 or 3*s*. 6*d*. Volumes I to VII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10-1 No. 1. The Fungi of India, by E. J. Butler, C.I.E., D.Sc., M.B., F.R.S. and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s*.

ICAR. 10-2 No. 2. Life-histories of Indian Microlepidoptera, Second Series: Alucitidae (Pterophoridae, Tortricina and Gelechiadae), by T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s*. 6*d*.

ICAR. 10-3 No. 3. The Open-Pan System of White-Sugar Manufacture, by R. C. Srivastava, B.Sc. (1935, 2nd edition). Price Rs. 3-2-0 or 5*s*. 6*d*.

ICAR. 10-4 No. 4. Life-histories of Indian Microlepidoptera: Cosmopterygidae to Neopseustidae, by T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1933). Price Rs. 4-8-0 or 7*s*. 6*d*.

ICAR. 10-5 No. 5. The Bombay Grasses, by E. J. Blatter, S.J., Ph.D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. Price Rs. 20-12-0 or 32*s*. 6*d*.

ICAR. 10-6	No. 6. Helminth Parasites of the Domesticated Animals in India, by G. D. Bhalerao, M.Sc. Price Rs. 7-12-0 or 13*s*. 3*d*.
ICAR. 10-7	No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng. and the Isolation of Types Resistant to the Disease, by W. McRae, M.A., D.Sc. (Edin.), F.L.S. and F. J. F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s*. 3*d*.
ICAR. 10-8	No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy, by C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s*. 9*d*.
ICAR. 10-9	No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah Shell Oil Storage and Distributing Company of India, Ltd., by C. P. G. Wade. Price Rs. 3-14-0 or 6*s*. 6*d*.
ICAR. 10-10	No. 10. The Spotted Boll-worms of Cotton in South Gujarat, by B. P. Deshpande and N. T. Nadkarny. Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 10-11	No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus Muscles and the Formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations, by H. N. Chelva Ayyangar, G.M.V.C. Price Rs. 4-10 or 7*s*. 9*d*.
ICAR. 10-12	No. 12. The Fungi of India, Supplement I, by B. B. Mundkur (*In Press*).

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8-1	No. 1. List of Publications on Indian Entomology (1930), by the Imperial Entomologist, Pusa. Price As. 14 or 1*s*. 6*d*.
ICAR. 8-2	No. 2. List of Publications on Indian Entomology (1931), by the Imperial Entomologist, Pusa. Price As. 8 or 10*d*.
ICAR. 8-3	No. 3. List of Publications on Indian Entomology (1932), by the Imperial Entomologist, Pusa. Price As. 12 or 1*s*. 3*d*.
ICAR. 8-4	No. 4. Host Plant Index of Indo-Ceylonese Coccidae, by S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. Price Re. 1-10-0 or 2*s*. 9*d*.
ICAR. 8-5	No. 5. List of Publications on Indian Entomology (1933), compiled by the Officiating Imperial Entomologist, Pusa. Price As. 9 or 1*s*.
ICAR. 8-6	No. 6. Bee-keeping, by C. C. Ghosh, B.A., F.E.S. (3rd Edition). Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8-7	No. 7. List of Publications on Indian Entomology (1934), compiled by the Officiating Imperial Entomologist and the Imperial Entomologist, Pusa. Price Re. 1-2-0 or 2*s*.
ICAR. 8-8	No. 8. Selected Clinical Articles, Part I, by G. K. Sharma, and R. L. Kaura. Price As. 8 or 10*d*.
ICAR. 8-9	No. 9. Statistical Methods and their Application to Agronomy: A Bibliography, by K. K. Guha Roy. Price Rs. 2-2-0 or 4*s*.
ICAR 8-10	No. 10. Diseases of Sugarcane and Methods for their Control, by L. S. Subramaniam. Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8-11	No. 11. Tables of Standard Errors of Mendelian Ratios, compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell), and P. Krishna Rao, L.Ag. Price As. 12 or 1*s*. 3*d*.
ICAR. 8-12	No. 12. List of Publications on the Botany of Indian Crops, Part II, for the Period 1928-32, by R. D. Bose. Price Rs. 3-6 or 5*s*. 9*d*.

ICAR. 8-13	No. 13. Two New Statistical Tables based upon Fisher's '*t*', by M. Vaidyanathan. Price As. 6 or 8*d*.
ICAR. 8-14	No. 14. List of Publications on Indian Entomology (1935), compiled by the Imperial Entomologist, Pusa. Price Re. 1-4 or 2*s*.
ICAR. 8-15	No. 15. Selected Clinical Articles, Part II, by G. K. Sharma, R. L. Kaura, S. Ganapathy Iyer, G. S. Khan and S. Mangrulkar. Price Re. 1-4 or 2*s*.
ICAR. 8-16	No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders, by P. E. Lander, M.A., D.Sc. F.I.C., I.A.S. Price Rs. 3-14-0 or 6*s*. 9*d*.
ICAR. 8-17	No. 17. A Brief Survey of Some of the Important Breeds of Cattle in India, by Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S. Price Rs. 2-0-0 or 3*s*. 6*d*.
ICAR. 8-18	No. 18. Milk Records of Cattle Dairy Farms in India by K. P. Kartha, (*In Press*).
ICAR. 8-19	No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province, by Hem Singh Pruthi, M.Sc., Ph. D. (Cantab.), F.N.I. and H. N. Batra, B.Sc., Assoc. I.A.R.I. (*In Press*).

6. Annual Reports of the Imperial Council of Agricultural Research

ICAR. 12-31	Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.
ICAR. 12-32	Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.
ICAR. 12-33	Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of stock).
ICAR. 12-34	Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Re. 1-8 or 2*s*. 6*d*.
ICAR. 12-35	Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.
ICAR. 12-36	Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.
ICAR. 12-37	Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Re. 1-2 or 2*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9-29	Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock).
ICAR. 9-31	Review of Agricultural Operations in India, 1929-31. Price Rs. 5 or 8*s*. 3*d*.
ICAR. 9-33	Review of Agricultural Operations in India, 1931-33. Price Rs. 5-12-0 or 9*s*. 6*d*.
	Agriculture and Animal Husbandry in India, 1933-34 and 1934-35.—
ICAR. 13-1-35	Part I.—Crop Production. Price Rs. 4-14 or 8*s*.
ICAR. 13-2-35	Part II.—Animal Husbandry. Price Re. 1 or 1*s*. 9*d*.
ICAR. 13-36	Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10 or 7*s* 9*d*.

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2	Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 3	Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s*. 9*d*.
VRI. I	A Description of the Imperial Institute of Veterinary Research, Muktesar and its Substation, the Imperial Veterinary Serum Institute, Izatnagar, by F. Ware, F.R.C.V.S. Price Re. 1-4-0 or 2*s*.
ARI. 7-187	The Production of Cigarette Tobacco by Flue-curing, by F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. and Kashi Ram. *Imp. Inst. Agri. Res. Pusa. Bull* No. 187. Reprinted (1935). Price Re. 1 or 1*s*. 9*d*.
ICAR. 16	A Handbook of Statistics for Use in Plant Breeding and Agricultural Problems, by F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s*. 3*d*.

Copies of the above publications can be had from—

The Manager of Publications, Civil Lines, Delhi, and from any of the Agents, a list of whom will be found on the inside page of the front cover.

Purchasers not residing in Asia should apply to obtain publications from the High Commissioner for India, India House, Aldwych, London.

NOTE.—When indenting please give only the symbol preceding the name of the publication.

APPENDIX

INSTRUCTIONS TO AUTHORS OF PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH*

1. All manuscripts should be clean, clear and carefully revised. Only one side of the paper should be used, and as far as practicable the original type-written copy and not a carbon copy should be sent. Capitals should be sparingly used, and all the necessary punctuation should be done in the MS. and not left for introduction in proofs.

2. The title of a paper should not be lengthy.

3. It is desirable that the MS. should have suitable heads and sub-heads. In numbering the principal divisions of a paper Roman numerals should be used. The use of Arabic figures and (*a*), (*b*), (*c*), etc., is generally reserved for numbering the sub-divisions coming under each head.

4. Articles submitted for publication either in the *Indian Journal of Agricultural Science* or in the *Indian Journal of Veterinary Science and Animal Husbandry* should be accompanied by abstracts for publication in *Agriculture and Live-stock in India*. Abstracts should be concise, but should be long enough to explain the matter dealt with ; ordinarily no abstract should exceed 200 words.

5. When a word or line is intended to be printed in *italics* it should be underlined with a single line, in SM. CAP. with two lines, in CAPITALS with three lines, and when in **Antique** (heavy type) with a wavy line (~~~~~~~~~~~~~~).

6. In descriptive matter, numbers under 100 and all numbers occurring at the beginning of a sentence should be in words.

7. Local names for crops, technical operations, etc., should be defined where they first occur in the text, *e.g.*, *rabi* (spring crop). The use of local weights and measures should be avoided as far as possible. Vernacular names, such as *jowar*, *bajra*, should be in italics without a capital letter, and each such name where it first occurs should be followed by its scientific equivalent in brackets, *e.g.*, *jowar* (*Andropogon Sorghum*). It is usual to write the initial letters of varietal names in capitals, *e.g.*, Striped Mauritius, Dharwar-American cotton and Broach cotton.

---

* Spare copies of these Instructions can be had on application to the Secretary, Imperial Council of Agricultural Research (Publication Section), New Delhi.

8. Botanical and zoological names are printed in italics and should be underlined in the MS., *e.g.*, *Triticum vulgare* L. ; *Diplodia Corchori* Syd. ; *Pyrilla aberrans* Kirby. The International rules of Botanical Nomenclature and the International rules of Zoological Nomenclature should be followed. The names of chemical substances should not be written with a capital letter ; they are printed in Roman type (*e.g.*, calcium carbonate, prussic acid).

9. The following and similar abbreviations may be used freely :—*viz.*, *e.g.*, *i.e.*, mm. (millimetre), cm. (centimetre), grm. (gramme), mg. (milligramme), c. c. (cubic centimetre), sp. gr. (specific gravity), lb. (pound), cwt. (hundredweight), in. (inch), ft. (foot), oz. (ounce), md. (maund), sr. (seer), ch. (chhattak). Other abbreviations should be used sparingly, if at all.

10. References to plates should be given within brackets, without prefixing the word ' see ' or ' cf. ', in the MS. itself, and should not be left over for introduction in proofs. For example, "The parasite (Plate X, fig. 4) was present late in 1906".

11. The word ' Table ' is preferable to ' Statement ', and tables should be numbered consecutively in Roman figures. Each table should have an explanation as a sub-head. It is more convenient for reference if tables can be printed horizontally ; for this purpose they should not exceed in width the printing measure of the page (5-in). *Example*—

TABLE IV

Results of water-saving experiments on wheat (Pusa 12) at Gungapur, Haripur and Sargodha, 1916-17

Station	No. of irrigations including the preliminary watering	Yield per acre in maunds and seers		Average yield per acre	
		Grain	Straw	Grain	Straw
		Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.
Gungapur	One	12 19½	20 10	9 34	21 17
Haripur	,,	8 31	19 14		
Sargodha	,,	8 12½	25 27½		

12. References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, the abbreviated title of the publication, volume and page. In the text the reference should be indicated by the author's name followed by the year of publication enclosed in brackets ; when the

author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in single year, these should be numbered in sequence and the number quoted after the year both in the text and in the collected references. This system of referencing is used in the *Biochemical Journal* with slight modification, and will be clear from the following illustration :—

> The work of Osborne and Mendel [1919, 1, 2] and Steenbock and Boutwell [1919] had indicated an association of the fat-soluble vitamin with the green parts of plants. This view was examined by Coward and Drummond [1921], who reported that vitamin A was not synthesised by etiolated shoots but that green leaves were active in its formation. Another worker [Wilson 1922], on the other hand, found that etiolated shoots if given in sufficient quantity could supply the fat-soluble vitamin and that this factor was therefore formed in the absence of light.

REFERENCES

Coward, K. H. and Drummond, J. C. (1921). *Biochem. J.* **15**, 530.
Osborne, T. B. and Mendel, L. B. (1919, 1) *J. Biol. Chem.* **37**, 187.
——————————(1919, 2). *J. Biol. Chem.* **41**, 549.
Steenbock, H. and Boutwell, R. (1919). *J. Biol. Chem.* **41**, 149.
Wilson, J. (1922). *J. Biol. Chem.* **51**, 455.

Abbreviations, as far as possible should follow the system adopted in 'A World List of Scientific Periodicals' published by the Oxford University Press.

13. Papers should be complete when submitted for publication. As alterations and additions at the proof stage cause both additional expense and delay, they should be resorted to as little as possible. In making corrections in proofs the recognised symbols which will be found in the 'Standard Dictionary' should be used. Second (page) proofs will be submitted to authors who should return them promptly.

ILLUSTRATIONS

14. As the *format* of the journals has been standardized, the size adopted being crown quarto (about 7½-in. × 9⅝-in. cut), no text-figure, when printed, should exceed 4½ × 5 inches. Figures for plates should be so planned as to fill a crown quarto plate—the maximum space available for figures being 5¾ × 8 inches exclusive of that for letterpress printing.

15. Photos or drawings for illustration should accompany the manuscript and each should bear on the reverse side the name of the paper to which it relates together with the title or legend, figure or plate number, and the size to be reproduced. When giving instructions for reduction linear measurements are understood ; thus 'half-size' means reduce to half the length and breadth, not half the area. A photograph should not be rolled up, nor pinned, and should always be packed flat. A complete list of plates and figures should always accompany the paper.

16. Line drawings should be made with clear black lines on smooth white paper, preferably Bristol board. Rough paper should be avoided. Care should be taken that all the lines are drawn firmly ; scratchy or grey lines, produced by the ink being thinned down, are not permissible. Drawings should be larger than the required size. All lettering should be neatly and clearly put in, care being taken to make all lettering sufficiently large to stand reduction.

17. For half-tone work copy should be made on glossy silver paper and of the same size or larger than the size required.

18. For three-colour work copy may be oil painting, water-colour, coloured photograph or coloured transparency, and larger than the size required. In preparing copy, one should use only the primary colours, in any combination, as only inks of primary colours are used in printing. Originals can be enlarged, if necessary, but this should be avoided if possible.

19. For detailed instructions regarding preparation of illustrations, it would be of advantage to refer to Mr. C. M. Hutchinson's article on " Photographic Illustrations " in the *Agricultural Journal of India*, Vol. XI, Pt. 3, July 1916, and Mr. A. W. Slater's paper on " The Preparation and Reproduction of Scientific Illustrations " in the *Proceedings of the Third Entomological Meeting*, 1919, which has been reprinted as *Bulletin No. 114 of the Agricultural Research Institute, Pusa.*

GIPD—S 3—658 IC of AR—4-3-38—800.

ORIGINAL ARTICLES

*THE PRESENT STATE AND FUTURE DEVELOPMENT OF POTATO BREEDING

BY

R. N. SALAMAN, M.D., F.R.S.

(Received for publication on 10th January 1938)

The title of this paper was chosen in order to give prominence to the question as to whether a point has not been reached in the history of economic potato culture at which new facts must be considered and new and far-reaching decisions taken.

In order to make my meaning clearer I would ask you to bear with me whilst I briefly survey the history of the potato since its introduction into Europe, at the end of the sixteenth century.

We may for convenience consider this history as divided into four periods.

Period 1.—From 1600 to 1700 A. D., our varieties were obtained by the selection of seedlings from naturally selfed berries on plants all deriving in a straight line by descent from Gerard's Potato which was introduced some few years prior to 1596.

Period 2.—Somewhere in the early part of the eighteenth century, potatoes probably reached England from the Continent, where all varieties had been in their turn derived from those introduced *via* Spain about 1570 ; one at least of such introductions we know had purplish tubers. It is probable that crosses between the two sources of potatoes were made as we now find evidence of dark purple-coloured tubers which could not have been derived from Gerard's, which was either white, or, at most lightly tinged with pink, but which might readily have resulted from a cross of the two.

Period 3.—The third period is sharply demarcated by two events : The potato disease and famine of 1845 and 1846, and the introduction into the U. S. A. in 1851 of fresh South American blood from Panama by means of the variety known as Rough Purple Chile from which, in generative succession, came Garnet Chile, Early Rose and Beauty of Hebron. From the last two the South American blood filtered through our English stocks. A feverish outburst of potato breeding ensued, and some of the most notable varieties ever produced resulted, *viz.* Magnum Bonum, Champion and Patterson's Victoria.

It should be observed that there is no evidence that Goodrich's new potato was other than a cultivated South American variety ; indeed, it is almost certain that it was not a wild species, nor should its name, Rough Purple Chile, be taken as any proof that it was derived from Chile. It was most probably one of the *Solanum andigenum* varieties grown locally. I would say here that in my opinion the original importations into Europe were also of the *andigenum* stock, a point of view not shared by the Russian workers.

---

* A paper read at the Indian Science Congress, Calcutta, 1938.

Period 4.—The discovery of the existence of Wart disease in England during the first decade of this century and the danger which threatened the potato crop, heralded a new era in variety production. No new blood was introduced by English breeders to deal with the problem, if we omit that derived from crosses with some of the German varieties which may have partaken of the blood of Daber, a variety reputed to have been derived from South America in 1830, and which had entered into the pedigree of several German varieties, resistance to Wart disease is controlled by genes to be found in many of our old domestic types.

A few attempts have been made to introduce new blood from wild species during the last fifty years, but, except for one or two of Wilson's introductions in which such is claimed but which are no longer grown, none have succeeded.

We see therefore that during three-and-a-half centuries, with a few negligible exceptions, we have been raising varieties by the simple process of kaleidoscopic re-arrangement of the same fundamental qualities with which we started. It will be further observed that the process of variety production, up till now, has been throughout one sided. We have eliminated by selective breeding those characters which have appeared to be economically undesirable, whilst retaining such as have enhanced the immediate value of the plant as a saleable crop.

How far this process has gone, the picture it presents in terms of genetic potentiality, has not been, I venture to think, adequately considered in the past. Let us for a few moments review the situation from this point of view.

Physical characters of the tuber which have been or are in process of being lost.—1, deep purple coloured skins; 2, deep red skins; 3, all red or purple-tinged flesh; 4, deep yellow canary-coloured, coloured flesh; 5, round as well as pear and finger shaped tubers; 6, deep-eyed tubers; 7, branching tuberculated tubers; 8, very large tubers; and 9, long stolons.

Physical characters of the haulm which have been or are in process of being lost.—1, the many-branched type; 2, the small narrow-leafed types; 3, wide spacing of leaflets; 4, reduced development of folioles; 5, types of haulm which tend to be stiff, upright and pointing; 6, types in which there is a heavy deposition of pigment in stem, leaf or flower; and 7, plants with fibrous roots.

Physiological characters of the plant which have been or are in process of being lost.—1, the reaction to short-day conditions, *i.e.* formation of tubers in an environment where the daylight during the growing season is twelve hours or less; 2, very early maturity; 3, very late maturity; 4, susceptibility to Wart disease; 5, resistance to blight; 6, true sexual fertility, especially that of the pollen; 7, low cropping capacity; and 8, resistance to frost.

Now it may be argued: "What cause of complaint is there? The majority of the characteristics which you state are more or less completely eliminated from the stocks of to-day are undesirable ones—good riddance to them." Yes, that is one way of looking at it, but let us regard the matter from another angle.

The elimination of the score or more distinctive characters enumerated, when regarded from the Mendelian point of view, means a loss of probably not less than a hundred separate genes or hereditary units.

If one compares a widely grown domestic potato variety of to-day, such as Majestic, with, let us say, a cultivated forty-eight chromosome potato from the Bolivian Andes, bearing highly pigmented, deep-eyed, round tubers, on a narrow-leafed, many-stemmed haulm, one realises that both will enjoy an enormous number of genes in common, *i.e.* all those genes which control the general morphological characters of the plant, whilst they will differ the one from the other by a relatively small number of genes. Now suppose that the number in which they differ is on a liberal estimate two hundred—then we see that by the elimination of all the so-called 'undesirable' characters we have cut out about half of the total number of hereditary factors or genes which might be at our disposal for the building of new varieties.

But this is not all. We know that the hereditary genes which may seem to control the exhibition of any one character do not, in fact, act independently of the remainder. For whilst they may dictate the characteristic type of pattern behaviour involved, the final structure and its adaptation to the whole organism is conditioned by the resultant interaction of the whole collection of such hereditary units. So much we know, or I would rather say, so little; but look for a moment at what we do not know, but what is eminently probable.

We eliminate, let us say, deep eyes, long stolons and highly coloured skins. How do we know that the genes responsible for these are not also of material importance in the maintenance of a successful symbiosis or tolerance towards the active agents of virus disease? I cite this possibility in particular because there is some evidence in its support.

We eliminate late maturity, numerous and upstanding stems, fibrous roots, and long stolons; are we sure that much of the plant's vigour or its resistance to frost may not have gone with them?

It is not necessary to enlarge on this aspect of the problem further than to point out that in the course of a little more than three centuries we have added nothing to the sum total of the potato's potentialities, whilst we have removed, discarded, and lost for ever about one hundred genic factors.

Let us now take stock of the cards which breeders have, so to speak, in their hands. All the necessary factors required are there to produce varieties with large crops of medium or large sized tubers, of oval or kidney shape with smooth eyes, and white or faintly parti-coloured skins, borne on extremely short stolons. In addition, the necessary factors which serve to link these characteristics up with resistance to Wart disease and any of the three main types of maturity are present. Not a bad hand it must be admitted, but one that calls for this comment:—

That the chances, so long as he is merely ringing the changes of the old parental and nearly uniform stocks of hereditary factors, are a thousand to one against the breeder producing anything outstandingly different from or better than that already existing. In fact potato breeding has reached almost the same position as that attained in the breeding of thorough-bred horses. The number of requisite and desirable characters have been so fined down, the undesirable ones so completely eliminated, the breeding so rigidly close, and one race-horse so much like another, that horse-racing has become far more a gamble on the external non-hereditary environmental factors, such as those which affect the individual horse by reason of his feeding, training and the like, than it is on any new genetic quality of the winner which he, rather than the loser, acquired from his parents. The Derby will always be won within three minutes and a small variable number of seconds; it will certainly never be won in two minutes, and almost as certain is it that no horse will require four minutes to complete the course.

In the same way we may gamble with the new varieties produced from our existing stocks, but we certainly cannot produce a really new variety with new and valuable qualities without a radical change of method. Effective potato breeding has almost come to a standstill.

It will be seen that in the course of 340 years we have succeeded in producing a highly specialized product capable of rendering, in a suitable environment, a food supply allowing of almost infinite extension.

Nor should we fail to acknowledge that the potato, well supplied as it is with most of the essential vitamins can, almost unaided by other foodstuffs, maintain a population in health—Ireland has taught us that lesson. The other side of the picture, the social degradation that is almost a necessary sequel of a cheap and easily grown assimilable food has yet to be reckoned with.

It is not too much to say that so long as we ensure the potato a favourable environment, it will play its part and the varieties by which today it is represented play that part to perfection. Indeed a veritable triumph of man's command over nature, but what if the environment is not favourable? What if diseases, some obvious, such as fungal attacks, others subtle and intangible as virus diseases, render the environment no longer favourable? What preparations—what genetic outfit has our potato with which to meet its enemies, whether climatic or parasitic, such as blight virus, frost, heat and drought?

We will consider the more important of these in detail directly, but before doing so, certain general principles must be considered.

I think it will be found to hold in most cases that any radical improvement designed to meet the requirements of a given environment, must be worked out within that environment. Thus you in India will doubtless require—or at least will desire—several different types of potatoes to meet widely different environments. It is essential that they should be created here in India. That India has herself recognized this truth is shown by the lead she has taken in the effort to galvanize the Empire into sending an expedition to South America in order to collect new genetic material for work, is a source of deep gratification to both you in India as well as to us in England. The pity is that the effort is in danger of being strangled at birth by the ludicrously small sum which has been devoted to it.

What the Russians achieved by three fully equipped expeditions working over a number of years, the British Empire hopes to effect in one season for a sum well under £2,000.

Here one may be excused a short digression. Why, it will be asked, has the world suddenly become 'potato-conscious'? There has been no dramatic failures of crops, no devastating epidemics to account for the sudden interest. Rather is the contrary the truth. The devices for combating disease by *ad hoc* treatment have become of late more efficient and their uses wider known. In Western Europe, with the exceptions already noted, we have developed the potato to something not far removed from the ideally perfect food crop. This new interest can be directly traced to the widespread interest and justifiable envy aroused by the expeditions sent out by Soviet Russia to America to search for new sources of tuber-bearing solanums and the rich material they have collected. The Russian work has made it abundantly clear that the time-honoured search for 'The Wild Ancestral Potato' is a delusion—there is no one ancestor, but a group of more or less closely related species, thirteen in number, several of which may have played some part in the production of our domestic potato. Far more important—for, after all, the question of ancestry is an academic one—is the fact that several of the wild species possess qualities lacking in our potato, the incorporation of which would be of high potential value. Among such qualities are resistance to blight (*Phytophthora infestans*) resistance to frost, heat and drought, resistance to virus disease, and it is claimed resistance to the attack of the Colorado Beetle.

It is only fair to say that Sutton and others attempted in the early years of this century to introduce the blood of wild potatoes into their cultures, but failed both to choose the right parents, and to surmount the difficulty of interspecific sterility. The writer demonstrated the existence of true genetic resistance to blight in 1908, both in *S. Edinense* and *S. demissum.* The latter source with further crosses made in 1914 and carried on to the present day have yielded a valuable source of resistance to blight, combined with serviceable economic qualities. As a historic fact the work at Barley, near Cambridge, was the first, that at Dahlem in Germany the second and the Russian the third to take part in the task of improving the potato by the introduction of the blood of distantly related species.

I may, I hope, be excused if at this juncture, I sound a note of warning. Our hopes, our justifiable expectations have been raised—let us not commit the blunder of thinking that the conversion of these expectations into economic reality is going to be an easy or rapid process. Believe me, it is a long uphill and tedious road, full of pitfalls, which must be traversed—but if the labour is much, the reward is great.

Let us now consider in some detail the possibility which the discovery of the new material opens up.

Resistance to blight.—It may be that our European stocks never possessed the genes necessary to establish a degree of resistance of any value ; if they did, they have now lost them and that beyond any hope of recovery so long as we confine our breeding to the use of existing domestic parental stocks.

With the material assembled in 1914 and maintained during the war, breeding with the new blood has gone steadily forward. During the last ten years, with the whole-hearted assistance of my late colleague, Miss Cecilia O'Connor, we have bred a number of seedling varieties which, in addition to most, if not all the desired qualities of a good domestic potato, display resistance to blight in both haulm and tuber. This resistance, it should be pointed out, is entirely independent of maturity.

But the fight against blight has not proceeded without reverses. No sooner had a complete resistance to the common blight been established than there appeared in our trial field a new bio-type or strain of the fungus which cut down our resistant stocks. Such a phenomenon, of course, is no new thing in this type of work, and it is well known to the cereal breeder who raises rust-proof stocks. The new form of blight, however, attacks our resistant varieties about one month after the common blight has shown itself on the ordinary domestic stocks. In 1936 the Cambridge resistant stocks were green and completely free from blight all through August and the first week or ten days of September by which time varieties such as King Edward and Majestic were black and shrivelled. Five or six weeks' extended freedom from attack was thus attained—no small gain.

The existence of this second type of blight was suspected in 1932 and from that time efforts were made to discover a source which resisted the second form and which could be employed for breeding purposes. In this we were successful, discovering in what is presumably a wild type from Ecuador, a potato possessing very high resistance to both the forms of blight. By crossing this with the first line of resistant stocks, and maintaining the economic qualities by back-crossing with domestic potatoes, seedlings have been raised which are resistant to both forms of blight and are of promising commercial value. Whether other aggressive strains of blight will be encountered we cannot say, but such is by no means improbable. However, should the sources of resistance already mentioned fail us, there are still others we are experimenting with, and for which we have to thank the Russian investigators. What is established beyond cavil is that we stand possessed of new parental types bearing valuable characters which have not been available hitherto to breeders, and from which it should not be difficult to produce high-resistance potatoes endowed with all the economic qualities we are accustomed to demand.

There exist to-day at Cambridge some dozen or more new varieties in each of which the following qualities are combined: (1) Resistance to the common form of blight in both haulm and tuber; (2) Early, second-early and main crop maturities respectively; (3) Resistance to Wart disease; (4) Good to high cropping capacity; (5) White and light-pink coloured tubers; (6) Large, round, oval, and kidney shaped tubers, respectively; (7) Smooth eyes; (8) Stocks which are free of virus but which are not immune or resistant to the same; and (9) Acceptable taste and cooking quality.

In addition, there are a few recently evolved seedlings which combine the aforementioned qualities with resistance to the new as well as the common form of blight.

The course of breeding pursued may be illustrated by the following pedigree.

A typical pedigree of one of the new stocks

Matings		Remarks
Parents	*S. demissum* × Seedling of domestic type	Combination of blight resistance and no crop with very high cropping capacity.
1st generation	● Selfed	Selection of most vigorous types. Crops all very small and tubers unsatisfactory.
2nd generation	● Selfed	Continuance of same—some rather better crops.
3rd generation	● × Domestic seedling	Strengthening of the domestic characters with notable improvement of crop and quality.
4th generation	● Selfed	Selection of resistant seedlings with more promising qualities.
5th generation	● Selfed	Continuance of same—selection of economic types.
6th generation	● × Sutton's Abundance	Introduction of resistance to Wart disease in combination with blight resistance, etc.
*7th generation	● × Katahoin	Introduction of tolerance to virus X and selection of above combination.
*8th generation	●	Seedlings combining blight resistance, Wart resistance, some virus resistance and good economic qualities.

* A large proportion of these two families are resistant to the common form of blight in haulm and tuber, and are also resistant to Wart disease.

In the genealogy shown above we can trace the sorting out of the genes and their re-assembling in the desired combination. From *S. demissum* have been obtained genes for blight resistance and this resistance, carefully carried forward, has been checked by repeated tests through eight generations in twenty-three years. At the same time its short-day periodicity has been exchanged for a long-day one, its tuberlessness for a large crop. When reasonably good economic character had been established, immunity to Wart disease was super-added in the sixth generation. In the seventh, a certain tolerance to the X virus was inserted.

There is no doubt that the process might be compassed in fewer years but the problem remains the same, *viz.* to keep fast hold of the desirable characters—blight resistance, etc.,—on the one hand and insert the other attributes without losing what has been won.

As in England and Germany, so doubtless will you find it in India necessary to weld into your new variety several different genes bearing immunity to blight. You will almost certainly try out all the sources of immunity such as *S. neoantipoviczii* ($2n=48$), *S. ajuscoense* ($2n=48$) and above all as many of the strains of *S. demissum* as you can obtain. You will find no resistance in the Chilean varieties and very little in the Peru-Bolivian ones. In particular *S. semi-demissum* ($2n=60$) should not be omitted because as the suppositious offspring of *demissum* and *antipoviczii* it may contain two different sources of resistance, its hybrids with the domestic type Rot Kargis are poor in crop and sterile but that should not deter workers from seeking some compatible mating which would enable them to carry on the breeding.

The enemy you are fighting is a many-headed Cerberus and whilst but a single one is left against which you have not provided a protective gene, you are not out of danger.

Frost.—A feature in potato breeding we owe entirely to the Russians is the introduction of frost-resistance into our cultures. The outstanding source of such resistance is found in the species *S. acaule*, a rosette type ($2n=48$) from the Andes in the neighbourhood of Cerro de Pasco. It only crosses with great difficulty with the common potato, but if first hybridised with *S. araca papa* ($2n=24$) or *S. Rybini* ($2n=24$) and then subsequently crossed with the domestic, the further breeding becomes easy.

S. demissum, in addition to the resistance some of its strain exhibits to blight, possesses a resistance to frost. Veselovskii in 1934 found that the seedlings derived from the mating (*S. acaule* × *S. goniocalyx* ($2n=24$) × *S. tuberosom* var. *alma*, *Centifolia*, and *Rawling kidney*) were very promising and that the *acaule* × *goniocalyx*, F_1 seedlings continued to flower at temperatures as low as —5·7°C. To a lesser degree many of the cultivated varieties of *S. andigenum* are in comparison with our domestic potato, resistant to frost. The Russians are specialising in the raising of new frost-resistant varieties and have devoted to this work a specially prepared station at Hibiny in the Arctic Circle. There seems good reason to believe that it will prove a considerably easier task to build up frost-resistant stocks than it will be to breed such as will withstand all the forms of *Phytophthora infestans.*

Heat and drought.—As regards resistance to either heat or drought I have no personal experience, nor do the Russian workers help us further than to state that in the wild species, *S. millani* ($2n=36$) and *S. medians* ($2n=36$), both of Peru, this property is exhibited.

Earliness and absence of the dormancy period.—These qualities are inherent in the species *S. phureja* ($2n=24$) and *S. Rybini* ($2n=24$). There is good reason to think that their use as parents, which is being pursued in Russia, may lead to the production of varieties producing two crops in the year.

Virus disease.—I have left to the last what is probably the most important and, to me, the most interesting problem of the modern breeder—the task of producing a variety either immune to, or unaffected by, any of the virus diseases.

In Europe virus disease has always been the major problem confronting the raiser of commercial seed, and through him the farmer and small producer. In England the difficulty has been tackled with considerable success from the potato-seed end. Both Government departments and seed raisers have encouraged the raising of seed in such districts and under such conditions where these diseases are at a minimum.

In practice this means the use of those districts in which the Green-fly is scarce or absent. Such districts are, in fact, those in which the moisture of the atmosphere is at the highest and the winds, preferably those from off the sea, blow the strongest. Altitude as such has no virtue. It is the Green-fly, *Myzus persicae,* which dictates our policy and which in Great Britain must even today entail an annual loss of something in the neighbourhood of £5 million.

When we consider how apart from cultural methods the problem may be solved, it will be convenient to consider the plan of attack from three different angles.

(a) *Defence by the raising of genetically resistant varieties*

In *S. Rybini* ($2n=24$) we have a species which the Russian workers claim to be naturally immune to virus disease. My own observations support this so far as I have failed to infect it with the two most important viruses, *viz.*, the ‘ Y ’ virus and Leaf-roll. In the U. S. A. the Government Department of Agriculture has raised a variety 41956 which has a grandparent a Chilean cultivated variety, the rest of its ancestry deriving directly from European domestic varieties—which is completely resistant to the ‘ X ’ virus. Here then for the first time in the history of potato breeding we find at our disposal genetic material which is endowed with a genuine resistance to some of the more important virus diseases affecting the potato.

(b) *Defence by the raising of carriers*

Breeders have, at all times, been in the habit of discarding seedlings showing early and characteristic signs of what in the past was generally called evidence of degeneration.

This so-called degeneration is, in fact, nothing else than the clinical expression of virus infection. Up till now all our potato stocks have shown themselves entirely devoid of any true resistance either to the entrance of any of the common viruses or to a localisation of such infection as opposed to its systemic distribution throughout the tissues of the plant.

Such plants as have appeared to withstand infection have been proved to be in fact saturated with the virus but to tolerate more or less completely its presence—they are spoken of as ' carriers '. Actually such tolerance in our domestic stocks does not extend either to Leaf-roll or to the ' Y ' virus with the exception of an otherwise valueless variety, Edgecote Purple. On the other hand most of our varieties show some tolerance to the less virulent strains of the ' X ' virus, whilst others such as Arran Consul and Up-to-date are tolerant to the ' B ' streak, a disease lethal to most of our best commercial stocks. King Edward, a universally popular variety is completely tolerant to the virus of ' paracrinkle ' from which its stocks are never free, a virus which has a crippling effect on Arran Victory, Arran Chief and Sharpes Expres.

The cultivation of tolerant varieties or carriers does unquestionably constitute an alternative policy of defence but not one which is likely to have a general application, seeing that the major diseases, Leaf-roll and the ' Y ' virus, escape it.

(c) *Defence by means of the protective inoculation of existing varieties*

So far this work is in its infancy. The principle enunciated by the writer is simple. If a plant be infected with a non-virulent strain of a given virus, then subsequent inoculation with a second strain of the same virus, no matter how virulent, will be without clinical effect.

The phenomenon, it must be emphasised, is essentially specific and a preliminary infection with one strain affords not the slightest protection against a second and unrelated virus.

The method has proved entirely satisfactory in regard to the ' X ' virus in the potato. Work is now in progress with a view to provide a like protection against the ' Y ' virus. Here the outstanding difficulty was that no non-virulent strain of the ' Y ' virus was known in nature with which to perform the initial protection. This obstacle has now been surmounted by the artificial attenuation of the common virulent form of the virus, and experiments on potatoes, at present confined to the glass-house, have proved decidedly promising. Attempts to deal with Leaf-roll on similar lines have failed.

But such failure need not be regarded as final. The outstanding difficulty at the moment is the impossibility, with our present technique, to convey the disease by sap inoculation.

It will be remembered that the viruses we are discussing normally become systemic within the plant. Hence an initial protective inoculation brings in its train the auto-infection of all the tubers the plant will subsequently give rise to. In this way it should become a practical and easy matter to induce an artificial or acquired protection in the entire stock of a variety in a very few years. We may, I think with some confidence, adopt an optimistic view with regard to efforts to combat the ravages of virus disease.

In conclusion I would urge that the times are propitious and our means increasingly more efficient for a united effort to improve in the not-distant future the potato stocks of the world. There is no reason why we should not provide ourselves with new varieties of the potato with all the economically desirable qualities which are to be found today in the domestic stocks, and at the same time endow them with a resistance to the majority of the diseases to which our present-day varieties are so susceptible.

The possession of varieties, such as have been suggested, would bring about economic stability to the producer and protection against scarcity and high prices to the consumer. In this work it is to be hoped that India, with her widely variant needs and her enterprising and effective scientific agricultural organisation, will take a foremost part.

In this lecture are incorporated certain portions of a paper " Potato Variety Production : a New Departure ", published in the *Gardeners' Chronicle,* October 30, 1937, to whom acknowledgment is made.

STUDIES IN PLANT BREEDING TECHNIQUE

III. CROP ANALYSIS AND VARIETAL IMPROVEMENT IN MALVI *JOWAR* (*ANDROPOGON SORGHUM*)

BY

J. B. HUTCHINSON

V. G. PANSE

N. S. APTE AND B. M. PUGH

Institute of Plant Industry, Indore, Central India

(Received for publication on 1st December 1937)

CONTENTS

PAGE

I. INTRODUCTION : J. B. H. 131

II. BOTANY : J. B. H. & B. M. P. 132

a. Classification 132

b. Crop analysis 135

III. PLANT BREEDING : J. B. H., V. G. P., N. S. A. & B. M. P. . . . 143

IV. DISCUSSION 148

V. SUMMARY 151

REFERENCES 152

I. INTRODUCTION

THE work here reported was commenced at the Institute of Plant Industry in the 1933 *kharif* (monsoon) season. It began as a straightforward programme of improvement by selection. With increasing understanding of the crop and the development of work on the status and composition of crop mixtures [Hutchinson & Ghose, 1937, 1], it became desirable to study the composition and variability of the local unselected crop in the field. This was done in the 1936 season. Concurrently with studies in variability, botanical classification was attempted with the aid of Snowden's [1936] monograph. The reconsideration of methods of description and classification of plant breeding material at present in progress in India suggested to the authors that the information obtained might suitably be written up as a single paper to illustrate what we consider to be the best line of attack on the problem of the classification and exploitation of variable crop populations.

As the investigation has been carried out in two distinct parts, the authorship of each section is indicated by initials.

II. BOTANY

(*a*) *Classification*

Snowden [1936] has recently revised the classification of the *Sorghums* on the basis of an extensive, Empire-wide collection at the Kew herbarium. He decided to follow Stapf in subdividing the group into numerous species rather than Koernicke and Hackel, both of whom regarded the cultivated types as varieties and forms of a single species. His reasons for adopting this course involve botanical and genetic principles of such importance as to justify the following somewhat lengthy quotation :

> " Although many of the cultivated Sorghums, like the species in numerous other genera of the Andropogoneae, show but little differentiation in their characters on dissection, there is a very wide range and much diversity in the shape and size of the fertile spikelets and grains, the texture of the glumes, and the relative size of the glumes and grains, and their relationship to one another. Where such differences are observed in wild grasses, particularly those occurring in widely separated areas, botanists have no hesitation in according specific rank to the most distinct types. To sink such distinctive races of cultivated Sorghums all under one species is a decidedly retrograde step, which possesses no advantages whether from the standpoint of the practical cultivator, the geneticist, the cytologist, or the systematist. Stapf has already pointed out (Prain, *Fl. Trop. Afr.* **9**, 105) that the recognition of the most distinct races as species has the advantages of simplicity and directness."

This involves the very disputable assumption that a species is a unit of classification the limits of which depend upon the convenience of the taxonomist and not upon the genetic attributes of the material. The natural genetic demarcation of species by chromosome differences and sterility barriers are now well understood, and the known facts of the cytogenetic situation in *Sorghum* have been given full weight by Snowden. Recently, however, chiefly as a result of Harland's [1936] work on cotton, another type of genetic demarcation of species limits has been demonstrated. Within the interfertile groups in the genus *Gossypium* there exist species differing so greatly in their genetic balance that crossing between them, though yielding vigorous and fertile F_1 hybrids, results in the production of a series of unbalanced and usually weakly forms in F_2 and later generations. The differences between the species in genetic balance are so great as to preserve their integrity in spite of natural crossing in mixed cultivations [Hutchinson and Ghose, 1937, 2; Hutchinson, 1937]. Recently [Hutchinson, 1937] it has been possible to trace the evolutionary history of the cultivated cottons, linking up the species genotypes with the development of agricultural types from different wild species, and to give a striking demonstration of the development by parallel evolution of closely parallel forms in different species. A similar treatment of the genus *Sorghum* would be of immense value to agricultural botanists. It appears from Snowden's work that several wild species have been involved in the origin of the cultivated sorghums, and he gives some indication of their probable relationships. Further development of this line of attack on the basis of adequate collections of living material may be expected to elucidate the relationships of the cultivated types to the wild species and provide the elements of a classification which will be acceptable to geneticists and plant breeders.

The extent of variability within a group has no necessary relation to the number of species into which it should be divided. There is a natural tendency for the collector to preserve extreme forms, and thereby to exaggerate the distinctions between types in herbarium material. With adequate samples —which can scarcely be obtained except in the field—it becomes obvious that the variability in many characters is continuous, while genetic investigations show that in others it is due to simply inherited differences. The separation of extremes of these types of variability into distinct species or varieties obscures the true relationship. Furthermore, within a group divided by no barriers of either sterility or differences in genetic balance, the whole range of plant characters may occur in all possible combinations and the taxonomist is faced with the alternative of naming as species and varieties all combinations available to him, or including the whole group in a single species and describing the range of variability occurring in the more important characters. The limited and selected nature of herbarium material results in a bias in favour of the former method among systematic botanists. Under field conditions, however, such a classification fails, as the number of combinations occurring is very much greater than the number preserved in herbaria, and to complete it would make it so voluminous as to be useless. The latter method is in accordance with the genetic interpretation of variability, and makes possible an adequate classification which can be made complete without becoming unwieldy.

The material available in Central India is representative of only one group of the cultivated *Sorghums*, and is therefore inadequate to form a basis for a classification on the lines suggested above. It is proposed to do no more than illustrate the failure of Snowden's classification to cover the variability observed. The main heads of Snowden's key will be considered in turn :

A. Sessile spikelets more or less lanceolate, elliptic, or oblong, usually twice as long as broad when in flower, never broadest above the middle even when in fruit, and never transversely wrinkled or depressed across the middle :

Of the material examined in the crop analysis (*see* below), one plant only was discovered agreeing with this description. It differed from the typical *jowars* of Central India (which composed the rest of the crop in which it occurred) solely in the size of the glumes, which were about three times as long as broad, and entirely enclosed the grains. Without genetic studies, it is not possible to decide the importance of the difference.

aa. Sessile spikelets more or less ovate to rotundate, obovate or rhombic, usually less than twice as long as broad when in flower, rarely elliptic or oblong and then broadest above the middle (either when in flower or when in fruit) or with the lower glume wrinkled and depressed across the middle, or (as usual) with the pedicels of the pedicelled spikelets 0·5-2 mm. long.

With the exception of the plant referred to above, all the Central Indian *jowars* examined fell in this class.

b. Sessile spikelets not transversely wrinkled and depressed about the middle ; lower glume coriaceous almost throughout, with the nerves usually more or less obscure except towards the tip, rarely crustaceous and somewhat striately nerved, but then with the grains enclosed or almost enclosed, and not readily separating from the glumes :

bb. Sessile spikelets either transversely wrinkled and depressed about the middle (and then with the glumes often thin and papery) or with a large strongly nerved herbaceous tip to the lower glume when in flower, broadly ovate to obovate, obovate-elliptic, obovate-oblong, rhomboid or almost hexagonal ; mature grains as long as or more often longer than the glumes (except *S. rigidum*) and readily separable from them ; pedicelled spikelets persistent ; pedicels 0·5-2 mm. long (except *S. rigidum*) ; panicle usually dense and compact, but sometimes loose ; rachis, branches and branchlets tomentose to villous (except *S. rigidum*) :

In the crop analysis studies (discussed below) records were taken of the texture, nervation and wrinkling of the lower glumes of the sessile spikelets. In all cases the glumes were coriaceous almost to the tip (never thin and papery) and the nerves were obscure. Both wrinkled or depressed and smooth glumes were observed, not only in the same crop samples, but also on the same earheads. The distinction between the two groups therefore fails.

Snowden's subseries *bicoloria* (under *b* above) can be eliminated, as no plants were observed on which the mature grains were enclosed or tightly clasped by the glumes. There remain subseries *caffra* (under *b* above) and subseries *durra* (under *bb* above). Though the key and descriptions fail to eliminate either group, *caffra* can be omitted from further consideration, as it is indigenous in Africa and is only recorded from India as an introduced type.

Of the subdivisions of subseries *durra*, *S. rigidum* did not occur, as no plants were observed with deciduous pedicelled spikelets. No other distinctions within the subseries held good in the field. All lower glumes were coriaceous, but some were transversely wrinkled and others were not. The mature grains were moderately compressed, but varied from rather broad at the top, and somewhat wedge-shaped at the base to much compressed and flattened, or almost orbicular. As the whole range of variation might be found in a single population, it would be impossible to rely upon the character to distinguish Snowden's *S. durra*, *S. cernuum*, and *S. subglabrescens*.

For the present purpose, it seems most satisfactory to adopt the name of the subseries which fits the material best, and to assign all the *jowars* of Central India to *Sorghum durra* Stapf.

(*b*) *Crop analysis*

A study was made of the *jowar* crop in cultivators' fields in the Malwa tract round Indore, and in the Nimar (Nerbudda valley) tract of Indore and Dhar States. Malwa is a plateau about 800 feet higher than Nimar, and separated from it by the narrow Vindhyan range. The soils of both areas are black, but that of Malwa is very sticky and retentive of moisture, while that of Nimar is more open and less retentive. On the whole the rainfall is lower in Nimar and the monsoon usually closes a little earlier. In consequence the Nimar *kharif* (monsoon) crops usually ripen a week or two earlier than those of Malwa.

Thirty-four samples were taken from cultivators' fields in Malwa and seven in Nimar. Each sample consisted of thirty plants in a row taken at random on entering the field. A number of taxonomic characters were studied in an attempt to classify the material according to Snowden's monograph. The result of the attempt is discussed above and taxonomic characters will not be considered further. The following characters of agricultural interest were recorded :—

Colour of the midrib of the leaf.
Panicle neck—whether straight, bent, or goose-necked.
Panicle density.
Grain colour.
Number of nodes per plant.

An attempt was also made to record glume colour, but it was found that this varied greatly with the degree of ripeness of the panicle, and as it was necessary to take the census on standing crops varying from green with the grain just hardening to dead ripe, glume colour records were discarded. Data for all samples are given in Tables I-IV.

TABLE I

Morphological characters of jowar *samples*

(*Malwa*)

Sample	Midrib colour		Neck			Panicle density					Grain colour	
	White	Green	Straight	Half bent	Goose necked	Very dense	Dense	Intermediate	Lax	Very lax	Yellow	White
1 . .	30	...	26	2	2	...	25	5	...	...	30	...
2 . .	30	...	24	5	1	18	8	4	...	...	17	13
3 . .	5	25	23	5	2	...	21	9	...	...	21	9
4 . .	12	18	30	...	...	...	6	19	5	...	28	2

TABLE I—*contd.*

Sample	Midrib colour		Neck			Panicle density					Grain colour	
	White	Green	Straight	Half bent	Goose necked	Very dense	Dense	Intermediate	Lax	Very lax	Yellow	White
5 . .	23	7	29	...	1	6	19	5	...	...	1	29
6 . .	9	...	17	7	6	2	21	7	...	...	10	20
7 . .	24	...	27	2	1	...	3	17	10	...	27	3
11 . .	28	1	22	7	1	...	11	19	...	...	25	5
13 . .	30	...	24	2	4	3	1	11	14	1	5	25
14 . .	18	12	29	...	1	7	12	8	1	2	7	23
15 . .	30	...	17	6	7	5	11	4	5	5	2	28
23 . .	12	6	21	1	8	8	13	5	4	...	30	...
24 . .	29	1	30	...	...	1	22	6	1	...	30	...
25 . .	30	...	28	...	2	...	...	3	23	4	...	30
31 . .	27	3	23	4	3	...	5	9	14	2	2	28
32 . .	30	...	13	11	6	...	25	5	...	...	14	16
33 . .	30	...	4	16	10	...	28	2	...	...	29	1
34 . .	30	...	26	3	1	...	...	1	24	5	25	5
35 . .	30	...	23	2	5	...	6	9	12	3	4	26
36 . .	30	...	23	4	3	...	10	19	...	1	30	...
37 . .	30	...	26	4	...	...	3	23	4	...	30	...
38 . .	30	...	23	7	...	7	19	4	...	...	30	...
39 . .	30	...	21	8	1	8	21	1	...	...	30	...
40 . .	29	1	30	...	...	...	...	...	3	27	...	30
41 . .	30	...	27	3	...	...	5	21	4	...	30	...
42 . .	30	...	23	4	3	...	9	15	6	...	12	18
43 . .	28	...	30	...	...	...	...	2	27	1	30	...
44 . .	30	...	24	3	3	5	13	5	5	2	16	14
45 . .	30	...	26	4	...	...	7	18	5	...	30	...
46 . .	29	1	30	...	...	...	4	15	11	...	19	11
47 . .	30	...	11	9	10	3	17	8	2	...	22	8
48 . .	30	...	26	2	2	...	3	10	17	...	29	1
49 . .	30	...	28	2	...	2	26	2	...	...	25	5
50 . .	30	...	16	10	4	3	23	4	...	...	30	...
TOTAL .	903	75	800	133	87	78	397	295	197	53	670	350
Percentage .	93	7	78	13	9	8	39	29	19	5	66	34

TABLE II

Morphological characters of jowar *samples*
(Nimar)

Sample	Midrib colour		Neck			Panicle density					Grain colour	
	White	Green	Straight	Half bent	Goose necked	Very dense	Dense	Inter-mediate	Lax	Very lax	Yellow	White
16 . .	26	4	29	1	...	...	10	12	8	...	29	1
17 . .	2	28	27	3	...	...	16	12	2	...	14	16
18 . .	27	...	18	11	1	1	17	11	1	...	(26 orange) 1	3
19 . .	...	...	21	2	7	4	17	9	...	...	...	30
20 . .	16	14	29	1	...	...	25	5	...	...	...	30
21 . .	12	7	29	1	...	4	7	16	3	...	14	16
22 . .	1	5	30	...	...	...	1	10	19	...	30	...
TOTAL .	84	58	183	19	8	9	93	75	33	...	88 (26 orange)	96
Percentage .	59	41	87	9	4	4	44	36	16	...	42 (12 orange)	46

TABLE III

Number of nodes per plant in jowar *samples*
(Malwa)

Sample	Nodes												Total	Mean
	8	9	10	11	12	13	14	15	16	17	18	19		
1 . .	..	6	10	7	4	3	..	..	..	..	..	..	30	10·6
2 . .	..	1	2	7	4	7	8	1	..	..	..	..	30	12·4
3 . .	..	1	3	3	3	7	7	2	4	..	..	..	30	13·0
4 . .	..	1	4	5	9	8	2	..	1	..	..	..	30	12·0
5 . .	..	..	..	8	13	7	1	1	..	..	..	..	30	12·1
6 . .	..	..	..	1	7	4	11	3	3	..	1	..	30	13·7
7 . .	..	..	1	7	12	6	3	1	..	..	..	..	30	12·2
11 . .	1	1	..	2	8	8	8	1	..	..	1	..	30	12·8
13 . .	..	..	3	4	9	5	5	2	2	..	..	..	30	12·4
14 . .	..	1	1	2	11	5	4	4	1	..	1	..	30	12·9
15 . .	..	..	1	6	9	9	3	2	..	..	..	..	30	12·4
23 . .	..	..	7	5	8	8	2	..	..	..	..	..	30	11·8
24 . .	..	2	8	13	6	1	..	..	..	..	..	..	30	10·9
25 . .	..	1	3	4	7	7	6	1	1	..	..	..	30	12·4
31 . .	..	..	1	1	8	6	6	5	2	1	..	..	30	13·4

TABLE III—*contd.*

Sample	Nodes												Total	Mean
	8	9	10	11	12	13	14	15	16	17	18	19		
32	..	..	1	1	7	8	4	4	5	..	..	..	30	13·5
33	..	..	..	1	8	12	4	5	..	..	..	..	30	13·1
34	..	..	1	4	14	5	4	..	1	1	..	..	30	12·5
35	..	..	3	6	6	8	2	5	..	..	..	..	30	12·5
36	..	..	3	4	5	8	4	6	..	..	..	..	30	12·8
37	..	1	9	9	4	5	1	1	..	..	..	..	30	11·3
38	..	..	..	4	3	4	7	10	2	..	..	..	30	13·7
39	..	..	..	5	7	11	5	1	1	..	..	..	30	12·8
40	..	..	8	9	10	2	1	..	..	..	..	..	30	11·3
41	1	1	5	5	7	5	6	..	..	..	..	..	30	11·8
42	..	..	4	3	..	7	9	4	2	..	1	..	30	13·3
43 Fodder	3	4	14	6	3	..	..	..	..	..	..	..	30	10·1
44	..	5	9	7	5	3	1	..	..	..	..	..	30	10·8
45	..	..	..	1	5	11	3	7	3	..	..	..	30	13·6
46	..	..	6	4	11	3	4	2	..	..	..	..	30	12
47	..	..	3	4	9	6	5	3	..	..	..	..	30	12·5
48	..	1	8	8	10	2	..	1	..	..	..	..	30	11·3
49	..	..	1	5	9	3	9	1	..	2	..	..	30	12·9
50	..	..	..	..	1	5	6	9	2	6	..	1	30	15·0
TOTAL	5	26	119	161	242	199	141	82	30	10	4	1	1020	12·4

TABLE IV

Number of nodes per plant in jowar *samples*

(*Nimar*)

Sample	Nodes													Total	Mean
	11	12	13	14	15	16	17	18	19	20	21	22	23		
16	..	7	11	6	5	..	1	..	..	..	..	..	..	30	13·4
17	2	1	10	10	4	3	..	..	..	..	..	..	..	30	13·7
18 Lal	..	..	1	3	1	4	3	4	8	4	1	..	1	30	17·8
19	..	..	1	4	6	7	6	3	1	1	1	..	..	30	16·2
20	1	6	7	8	4	3	1	..	..	..	..	..	..	30	13·7
21	..	..	2	3	7	4	9	4	..	1	..	..	..	30	16·1
22	..	..	..	7	7	10	3	3	..	..	..	..	..	30	15·6
TOTAL	3	14	32	41	34	31	23	14	9	6	2	..	1	210	15·22

Comparison with data from the cotton census of the same tracts [Hutchinson and Ghose, 1937, 1] reveals a striking difference in the amount of variation between samples. In cotton the sale of the crop to merchants who deal with it in bulk, and the mixing that takes place in ginneries, has resulted in a comparatively uniform mixture in each of the main cotton-growing tracts. Apart from the results of a rough seed selection practised by the cultivators of Nimar, it was only in Rajputana, where each man maintains his own seed supply, that there was any marked heterogeneity between samples. With a food crop, grown primarily for home consumption, from seed set aside by the cultivator from his own crop, there is much more opportunity for selection according to individual preference. This is most marked, as would be expected, in grain colour. Some prefer yellow *jowar* for eating, and some white, and in both Malwa and Nimar the majority of the samples were either pure or nearly pure for grain colour. In Nimar also, a distinct strain is grown for parching, which is fairly pure for orange-red grain (Table II, sample 18).

Differences between samples in panicle density, the type of panicle, neck and the number of nodes per plant were less pronounced, but were still considerable. It is not so easy to assign a cause to them as to differences in grain colour, as they do not appear to be connected with any particular economic advantage or quality preference. Plants with green midribs were rare in Malwa, and were practically confined to five samples. In Nimar all samples examined, except one, contained them in considerable numbers. It may be noted that owing to the loss of the green colour on drying, it was not possible to classify dead ripe plants, and the records are therefore incomplete for this character.

The differences in crop composition between the two tracts were small compared with those observed in cotton [Hutchinson and Ghose, 1937, 1]. In panicle density and type of neck the differences between the Malwa and Nimar samples were small compared with the differences between different samples in the same tract. In Malwa there was a larger proportion of yellow-grained samples than in Nimar, and the orange-red type of which a number of fields were seen in Nimar was only seen once in Malwa. Nimar samples, also, had more nodes per plant than those of Malwa.

Nodes per plant

Tract . . .	Mean	$V(M)$	
Malwa . . .	12·42	0.0031	d=2·80
Nimar . . .	15·22	0.0231	σ (d)=0·162

If the orange-red '*lal jowar*' sample is omitted the Nimar mean falls to 14·8 which is still significantly higher than the mean for Malwa. Height measurements were not taken, but in general samples with a high mean number of nodes were taller than those with a low mean. The '*lal jowar*' sample was particularly tall.

No associations between either midrib colour or number of nodes, and other characters were observed. Grain colour and shape of neck, however, were both associated with panicle density. Data for the associations are summarised for Malwa and Nimar separately in Tables V-VII below.

TABLE V

Shape of neck and panicle density in jowar *samples*

Shape of neck		Very dense	Dense	Inter-mediate	Lax	Very lax	Total
				Malwa			
Straight .	Observed .	50	268	253	179	50	800
	Expected .	61	312	231	154	42	..
Half bent .	Observed .	20	77	24	12	0	133
	Expected .	10	52	39	26	7	..
Goose necked	Observed .	8	52	18	6	3	87
	Expected .	7	33	25	17	4	..
TOTAL .	..	78	397	295	197	53	1020
				Nimar			
Straight .	Observed .	3	77	70	33	..	183
	Expected .	7·8	81·1	65·4	28·8	..	..
Half bent .	Observed .	2	13	4	0	..	19
	Expected .	0·8	8·4	6·8	3·0	..	..
Goose necked	Observed .	4	3	1	0	..	8
	Expected .	0·3	3·5	2·9	1·3	..	..
TOTAL . .	..	9	93	75	33	..	210

Malwa : χ^2 (independence) $=73 \cdot 2$; $n=8$; P very small indeed.

Nimar : The half bent and goose-necked classes were added together on account of the small numbers involved. χ^2 (independence) $=13 \cdot 5$; $n=4$; $P<0 \cdot 01$.

TABLE VI

Panicle density and grain colour in jowar *samples*

Grain colour		Very dense	Dense	Intermediate	Lax	Very lax	Total
			Malwa				
Yellow . .	Observed .	56	277	217	111	9	670
	Expected .	51	261	194	129	35	..
White . .	Observed .	22	120	78	86	44	350
	Expected .	27	136	101	68	18	..
TOTAL .	..	78	397	295	197	53	1020
			Nimar (orange-red sample omitted)				
Yellow . .	Observed .	1	16	41	29	..	87
	Expected .	3·9	36·7	30·9	15·5	..	..
White . .	Observed .	7	60	23	3	..	93
	Expected .	4·1	39·3	33·1	16·5	..	..
TOTAL .	..	8	76	64	32	..	180

Malwa : χ^2 (independence) = 76·2 ; $n=4$; P very small indeed.
Nimar : χ^2 (independence) = 54·8 ; $n=4$; P very small indeed.

TABLE VII

Shape of neck and grain colour in jowar *samples*

Grain colour		Straight	Half bent	Goose necked	Total
		Malwa			
Yellow . . .	Observed . .	521	97	52	670
	Expected . .	526	87	57	..
White . . .	Observed . .	279	36	35	350
	Expected . .	274	46	30	..
TOTAL .	..	800	133	87	1020
		Nimar			
Yellow .	Observed . .	85	2	0	87
	Expected . .	79·6	3·9	3·4	..
White . . .	Observed . .	80	6	7	93
	Expected . .	85·4	4·1	3·6	..
TOTAL .	..	165	8	7	180

Malwa : χ^2 (independence) = 4·7 ; $n=2$; P = 0·1
Nimar : χ^2 (independence) = 6·9 ; $n=2$; P = 0·1

In both Malwa and Nimar the very dense and dense classes contained significantly more half-bent and goose-necked plants than were to be expected on random assortment. In Malwa fewer yellow-grained plants were lax or very lax, and in Nimar more yellow-grained plants were intermediate or lax than were to be expected on random assortment. There was no significant departure from random assortment between type of neck and grain colour. It may be suggested that in both tracts there is a preference for a dense panicle. This appears to be stronger in Nimar than in Malwa, as no very lax panicles were recorded there. The association of goose neck with dense panicle cannot be ascribed to the action of human selection, since goose neck in most samples comprised only a small proportion of the crop. The association between panicle density and grain colour, on the other hand, is probably due to human preference, and this conclusion is supported by the fact that in Nimar, where more cultivators appear to favour white in preference to yellow grain, white grain is associated with a denser panicle, whereas in Malwa, where the majority appear to favour yellow grain, yellow grain is associated with a denser panicle.

A group of early types of *jowar* is grown in the hilly tracts in the westernmost states of Central India. On account of the partial failure of the 1936 monsoon in these areas, it was not possible to extend the census to include them. They are kept distinct from the main crop *jowars* and when grown at Indore they ripen ten days to two weeks earlier. So far as morphological studies can show, however, they give every indication of being no more than strains selected for earliness from the same population as the main crop *jowars*. Apart from the early types, the samples represent adequately the *jowar* crop of Central India. Various names are given to different types in the crop, and a number of them have been quoted by Snowden. An attempt was made to determine whether names were applied to easily distinguishable types which might reasonably be called crop varieties. It was found that in most cases the names cited by Snowden were simply a vernacular description of some prominent characteristic—*e.g.*, grain colour—of the plant. The varietal names given to us by cultivators in the course of our census work were applied by different people to such different groups of types that we concluded that in the main crop no well-marked varietal distinctions are recognised. In Nimar there is the orange-red '*lal jowar*' mentioned above. This is distinct both in grain colour and in the number of the nodes on the main stem, and it also has a somewhat different panicle shape from the main crop types. It is kept fairly pure and is grown for parching only. With the exception of this and the early types the *jowars* of Central India may be regarded as a single inter-breeding crop population, in which sub-populations differing in characters of agricultural importance are maintained by human selection.

III. PLANT BREEDING

When the present investigation started there were a number of Bombay and Central Provinces strains of grain *jowar* growing on the Institute farm. Variety trial data showed that four Central Provinces strains, Ramkel, Saoner, Lambkhansi and Detha, were well suited to Central India, and these were therefore included in the plant breeding programme. Subsequently a considerable range of Indian strains from the United Provinces, Bombay and Madras, and foreign ones from Iraq, Palestine, America and Australia was tested against the local Malvi. None were of sufficient promise in the black soil of Indore to be worthy of further attention.

Breeding work was started in 1933 with the local *jowars* of Central India and with the four promising Central Provinces strains, all of which appeared sufficiently variable to justify selection within them. A large number of single head selections were made in the 1933 crop. In 1934 forty-nine of the best of these were sown in a ten-block randomised progeny row trial, each plot consisting of a single row 10 feet long [Hutchinson and Panse, 1937, 1] with local Malvi as a control. The others were mixed according to grain colour and sown as two bulk crops (one yellow grained and one white grained) for mass selection. In order to reduce the interference of environmental factors in selection, the bulk crops were divided into 10 feet × 10 feet squares at harvest, and the best plant selected in each square. The plants selected, therefore, were those that had done better than their immediate neighbours. The selected material from each type was bulked and sown again in 1935 and the process repeated. Selected material from the 1935 crops of each type was tested against the products of the progeny row selection work and the local in a variety trial in 1936, and the results are reported below.

The yield data of the progeny row and 'small bulks' trials from 1934 to 1936 are given in summary form. Yields are given as percentages of the control where a control was included, and as percentages of the mean yield where it was not. Yields which do not differ significantly are included within brackets. Detailed analyses are not given, but standard errors as percentages of the mean yield are included as a measure of the efficiency of the experiments. To save space only the ten highest yielding progenies of the 1934 progeny row trial are included.

Progeny rows

1934 Ten best progenies											
Progeny .	20	3	11	5	12	26	44	18	17	1	Local
Yield (percentage of local)	152	147	146	144	132	131	130	129	128	128	100

Standard error 12·8 per cent

1935					
Family . .	18	12	11	20	3
Yield (per cent of mean)	107	103	103	97	91

	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)
Standard error	3	115	3	112	6	120	7	121	8	112
	9	113	5	109	5	117	6	120	4	111
Family comparisons 2·7 per cent	8	112	9	109	1	111	2	102	1	108
	2	109	4	105	2	103	4	101	3	107
Progeny comparisons 8·5 per cent	4	104	6	104	3	101	10	96	7	103
	5	101	7	100	7	96	9	95	5	98
	10	96	2	95	9	93	3	94	6	97
	7	85	8	92	10	92	1	92	2	92
	1	84	10	91	8	89	5	89	10	88
	6	81	1	83	4	78	8	89	9	84
	Included in 1936 bulks		Included in 1936 bulks		Included in 1936 bulks					
	18-3 in 1936 progeny rows		12-3 in 1936 progeny rows		11-6 in 1936 progeny rows		20-7 in 1936 progeny rows		Discarded	

1936								
Family . .	5	26	17	11-6	20-7	12-3	44	18-3
Yield (per cent of mean)	116	111	107	104	98	95	88	80

	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Progeny	Yield (per cent of mean)	Discarded without analysis of progenies
Standard error of family comparisons 6·1 per cent.	1	108	3	122	2	117	3	115	2	105	
	2	102	2	96	1	101	2	111	1	100	
	3	90	1	82	3	82	1	74	3	95	
Standard error per cent (progenies)	8·2		10·7		10·1		12·6		10·3		

Small bulks

The 1935 bulks were obtained by bulking the seed left after selection for progeny rows from the ten best yielding progenies in the 1934 progeny row trial.

1935			1936	
Strain	Yield (per cent of local)	How used in 1936	Strain	Yield (per cent of local)
26	148	Included in bulks, and selections made and included in progeny row trial.	5	124
5	148		26	105
17	135		17	102
20	119	Bulk discarded	Mass	. .
			selected	
12	119	Replaced by seed from progeny row trial	white	102
			Late	102
44	118	Bulk discarded. Selections included in progeny row trial.	12	102
			Mass	
			selected	
11	109	Replaced with seed from progeny row trial.	yellow	100
18	103		Local	100
Local	100		18	96
1	99	Discarded	11	94
3	91			
Standard error 4·6 per cent				3·8

In the 1934 progeny row trial there were large and highly significant differences between progenies, the first four progenies giving a significantly greater yield than the local. The ten highest yielding progenies were retained. Of these, the first three, and two others with high grain weight, were selected for the next progeny row trial. From each of them the best ten single plants were selected, giving in 1935 an experiment with five families, each with ten progenies. The remaining seed of the selected 1934 progenies was bulked progeny-wise. This gave ten small strain bulks, which were included in a ‘ small bulks ’ variety trial in 1935, arranged in six randomised blocks with 1/50 acre plots.

The ‘ small bulks ’ trial showed that four of the six highest yielding strains had been left out of the progeny row trial. Three good plants were selected from each of them, and were included in the 1936 progeny row trial with three selections from the highest yielding progeny in each of the four highest yielding families of 1935.

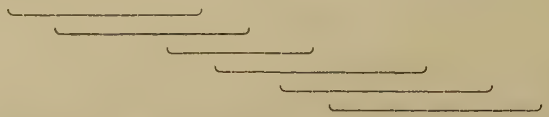
The three highest yielding families in 1936 (5, 26 and 17) were the ones which were brought back into the progeny row trial on account of their high yield in the 1935 ‘ small bulks ’ trial. The fourth family brought back from the ‘ small bulks ’ (44) was low in yield, coming last but one, and it, 12-3 and 18-3 were discarded without detailed analysis of their progenies. In the remaining five families, differences between progenies were significant in family 26 and suggestive in 17 and 11-6. They were small in 5 and 20-7. In this year's progeny row trial, yields were corrected for stand.

A 'small bulks' variety trial was also conducted in 1936, again with 1/50 acre plots and six replications. Included in it were the three highest yielding strains from the 1935 'small bulks' trial, bulks made up from the three highest yielding families in the 1935 progeny row trial, yellow-grained and white-grained strains from the mass-selection experiment, a bulk from a selection experiment with late *jowar* varieties, and the local as control.

Strains 5, 26 and 17 again gave the highest yields, but only 5 was significantly superior to the local. Strains 18 and 11 yielded less than the control, and were discarded. The two mass-selected strains showed no superiority over the local.

In 1936 there were heavy rains just before harvest, and the ripening grain moulded seriously. When the small bulks were threshed the proportion of mouldy grain was estimated carefully for each plot product and the data analysed. Below are given strains in order of merit, those not differing significantly being bracketted together. Mouldiness is expressed as the estimated percentage of mouldy grain.

Strain	26	5	Late	Yellow	Local	18	White	11	17	12	Standard error per cent
Per cent mouldy . . .	25	28	28	30	35	38	40	43	45	48	9·9



It may be noted that all strains better than the local had yellow grain, and all those worse than the local had white grain.

The chief interest of the summaries lies in the estimation of the efficiency of the selection process. Three seasons' mass selection has produced no appreciable effect, but judgment on its efficiency must be suspended until it is possible to test strains that have been selected over a longer period. Progeny row selection, on the other hand, has resulted in definite progress. Strain 5 has outyielded the local by significant amounts in all three trials in which there was a local control, and gave the highest yield (significantly higher than five out of the seven other families) in the remaining trial in which it was included. Strains 26 and 17 exceeded the local in all three trials, in which there was a control, by significant amounts in 1935, and were second and third in the 1936 progeny row trial.

The remaining strains gave no evidence of consistent superiority, and it is important to note that there were considerable differences in the order of merit from year to year. That such differences should occur is not surprising considering the variation in environment from season to season, and the highly heterozygous nature of the material under selection.

In addition to yield, observations were made on germination. In the 1935 progeny row trial there were no significant differences in percentage germination. In the 1936 trial there were significant differences in germination between families and between progenies in three out of eight families. The 1936 'small bulks' trial was drill sown. Germination counts were not taken, but marks were allotted on a scale from 0 to 10 for evenness and completeness of germination in each plot. Analysis showed that there were significant differences between strains. Results are summarised below :—

Progeny row trial

Strain	12-3	18-3	11-6	17	20-7	44	26	5	Standard error per cent
Germination per cent	86	86	84	84	82	82	74	74	2·3
Progenies and their germination per cent	C 87 B 85 A 84	B 87 A 86 C 83	B 90 C 90 A 72	C 90 B 82 A 79	C 84 B 82 A 81	B 84 A 81 C 80	C 83 A 77 B 63	A 78 C 73 B 72	
Standard error per cent	2·5	2·7	2·5	4·0	3·6	3·7	4·0	4·6	

Small bulks trial

Strain	18	Late	12	11	Local	Mass selected yellow	5	17	Mass selected white	26
Marks allotted	53	52	50	50	47	45	42	40	39	38

Standard error per cent 8·1

For strains included in both trials, agreement in the order of merit is good. It appears that the three strains (5, 17 and 26) which have given evidence of superiority in yield, are rather low in germination capacity. Differences between progenies, however, encourage the belief that 17 and 26 will respond to selection.

In designing the breeding scheme the 'small bulks' trials were included from the beginning in the hope of speeding up the isolation of improved strains. It was argued that since the cultivator has always grown a mixed population there was no need to insist on a high degree of purity before giving out a strain with a better yield, and therefore if a bulk from the early selection stages could be proved superior, it would be of value as a first improvement until later, more homozygous, products of selection were available. During the course of the experiment the policy of testing small bulks in the early stages received support from Hutchinson and Kubersingh's [1936] analysis of the efficiency of selection in Malvi cotton, where it was shown that the greater part of the advantage gained was from the isolation of strains superior from their first selection in the field, and not from the improvement of the strains in response to selection in the breeding plots.

Success has been achieved in isolating a *jowar* strain which was superior from its first selection, but the progeny row data provide no information concerning changes within strains in response to selection. That the necessary genetic variance is available is shown by the frequent occurrence of significant differences between progenies of the same strain. An *ad hoc* experiment was therefore carried out on strains 12-3 and 20-7 in 1936 and demonstrated a significant improvement during the selection period in germination capacity in both strains and in standing power in one of them. No improvement in yield was demonstrated, but unfortunately both strains turned out to be inferior in the 1936 progeny row trials, and no information is available concerning the response to selection in the better strains.

The efficiency of plant breeding work would be greatly improved by the use of methods which would enable the breeder to evaluate his progress at frequent intervals. The addition of small bulks trials to the ordinary progeny row breeding scheme is a first step in this direction. In the light of experience gained in the present work it may be suggested that the small bulks trials might profitably be enlarged to include a wider range of the products of selection in each generation. Then, in addition to testing for superiority to the local control, it would be possible to estimate the efficiency of selection by the study of the covariance between progenies in one year and small bulks grown from them in the next.

IV. Discussion

The indigenous crops of India are made up of highly variable populations. They have been studied in the past chiefly by the method of isolation and description of ‘ unit species ’. Large collections of material have been made, often from a number of provinces, as in the case of the Pusa studies, or representative of a single province, as in studies by Provincial Economic Botanists, and groups of morphologically distinct types have been isolated, described and keyed out. These studies are primarily taxonomic in outlook, and obscure many of the facts of variability of primary importance to geneticists. They take no account of the proportions in which the different manifestations of a character occur in the population, of the probability of other character combinations occurring, or of correlations between characters, and they lay disproportionate emphasis on easily identified character differences, which may be of little or no importance from the point of view of survival value. Parallel studies of the same crop in different provinces have recently led to the publication of separate type series, in which the same combination of morphological characters may occur under different numbers. Attempts to co-ordinate results reveal the fundamental flaw inherent in the method, that two strains with the same combination of easily recognisable morphological characters may differ in a wide range of physiological characters affecting their yield, response to climatic factors, or adaptability to soil type. As a description of variability, therefore, ‘ unit species ’ classifications are fundamentally defective, and a crop analysis such as that described above for *jowar*, and by Hutchinson and Ghose [1937,1] for cotton, is offered as a method of obtaining much of the required genetic information. Strain descriptions are still necessary for the classification of plant-breeding material, and should be published in compact form for the information of other workers in search of suitable material for breeding projects. Below (Tables VIII and IX) are given in tabular form descriptions of the *jowar* strains included in the 1936 'small bulks' trial as an illustration of a type of description adequate for the purpose of recording the range of breeding material available. (Yields are given from the 1936 trial, as not all strains were included in the 1935 trial. Yield data would be better estimated from the mean of three years' trials).

TABLE VIII

Morphological characters of Indore jowar *selections*

Strain	Midrib colour		Neck			Panicle density					Grain colour		Yield (percentage of local)
	White	Green	Straight	Half bent	Goose necked	Very dense	Dense	Intermediate	Lax	Very lax	Yellow	White	
5 .	30	...	24	4	2	...	1	11	14	4	24	6	124
11 .	28	2	27	2	1	...	2	28	...	...	...	30	94
12 .	29	...	29	1	...	...	1	29	...	...	...	30	102
17 .	29	...	22	7	1	...	1	9	17	3	...	30	102
18 .	29	1	28	1	1	...	...	18	11	1	...	30	96
26 .	28	2	7	6	17	28	1	1	...	...	29	1	105
White (mass)	29	...	22	6	2	...	...	15	15	...	...	30	102
Yellow (mass)	22	2	16	9	5	8	20	2	...	...	30	...	100
Late (yellow)	2	25	21	6	3	1	19	8	2	...	29	1	102
TOTAL	226	32	196	42	32	37	45	121	59	8	112	158	

TABLE IX

Number of nodes per plant in Indore jowar *selections*

Strain	Number of nodes												
	8	9	10	11	12	13	14	15	16	17	18	19	20
5	..	..	..	1	10	10	6	1	1	1	..	..	..
11	..	..	3	5	7	5	6	4	..	..	..	..	..
12	..	3	8	3	7	7	2	..	..	..	..	..	..
17	..	..	..	2	..	..	6	10	5	4	2	..	1
18	..	..	..	2	6	9	9	4	..	..	..	..	..
26	..	..	..	..	2	2	6	4	8	7	1	..	..
White (mass) . .	..	1	..	2	2	5	13	3	3	1	..	..	..
Yellow (mass) . .	1	..	1	1	7	3	5	7	3	1	..	1	..
Late (yellow) . .	..	..	..	2	1	6	5	3	7	5	1	..	..

The crop analysis gives both the range of morphological characters available in the tract, and the proportions in which different characters occur in the crop. It shows what the result of combined human and natural selection has been, and makes a sound basis for improvement work by providing information on what material is available and what types have actually been favoured. In the present case there is a single variable inter-breeding population in which distinct types are maintained in each tract by human selection, but the differences between the crops of the two main tracts (Malwa and Nimar) are small. If differences exist between the crops of the two tracts, therefore, they are in physiological characters that are not correlated with morphological. Further, the breeder will have to provide at least two strains (yellow and white grained) to meet the demand in each tract.

In the plant breeding work large and significant differences between progenies were demonstrated in each year. Considering the magnitude of the differences, and the fact that the locally grown type is a mixture of such material, it was thought that the isolation of superior strains and the further improvement by selection of those that were initially desirable would be simple and rapid. One definitely superior strain and two more of considerable promise have, in fact, been isolated, and some improvement within less valuable strains has been demonstrated. The results attained represent a very satisfactory rate of progress on ordinary plant-breeding standards, but further work on the effect of selection in the best strains is necessary before an estimate can be made of the extent to which the available genetic variance has been exploited. Consideration of the behaviour of a group of strains in successive years suggests that differences in response in different seasons are an important factor in reducing the rate of improvement. Further, the crop-analysis data on both *jowar* and cotton, and general observations in other crops, show that the equilibrium condition between crop variability and combined human and natural selective forces is a balanced mixture, and not a pure type. In other words, the survival of the fittest is of the fittest population and not the fittest type, and the fittest population is a mixture of types. If this is a justifiable conclusion from the nature of crop populations, the possibility of producing a pure strain superior to the local crop population will be related in no simple way to the extent of the genetic variance available. The attempt to produce a superior mixture by mass selection has had less success than the progeny row breeding work, and there is no doubt that line breeding offers the best prospect of success in crop improvement. Further work on crop populations, and in particular on the relation of the component genotypes to the behaviour of the whole, is urgently needed, and may be expected to be of great importance for the improvement of breeding technique. Meanwhile, it may be suggested as a first step that the breeder should be careful to maintain a wide range of strains in his breeding work, partly in order to guard against failure if his best ones prove ill adapted in some part of the range of environmental conditions, and partly to facilitate the accumulation of information on the nature of strain adaptability.

V. SUMMARY

The present status of *jowar* in Central India has been surveyed and the possibilities of crop improvement by selection studied.

Field studies showed that Snowden's [1936] classification is inadequate to the needs of agricultural botany. For a satisfactory classification it will be necessary to combine studies of a range of crop populations with genetic investigations of the relationships between wild and cultivated types. The *jowars* of Central India are assigned to one of Snowden's main groups (*Sorghum durra* Stapf), and it is shown that the limits of at least three of his species in this group are transgressed in the single, variable, inter-breeding crop population.

A crop analysis carried out in Malwa and Nimar revealed much less difference between the crops of the two areas than was the case with cotton [Hutchinson and Ghose, 1937, 1], but the variation from sample to sample in the same area was much greater. The latter is ascribed to the fact that each cultivator keeps his own seed and selects it according to his own preferences. To meet individual preferences it will be necessary to breed at least two strains (yellow and white grained) for each tract.

Two years' mass selection had no appreciable effect on the yield of Malvi *jowar*.

Progeny row selection was supplemented by the testing in randomised block trials of small bulks made up from seed left over after selection for subsequent progeny row trials from the best progenies, and also from seed of progenies not quite good enough for retention in the progeny row trials. The 'small bulks' trials were instrumental in saving valuable strains which would otherwise have been discarded, and one of these has proved significantly superior to the local in yield in three successive seasons. Two others of considerable promise have also been isolated.

Progeny row work was carried out in replicated randomised blocks as described by Hutchinson and Panse [1937]. Large and highly significant differences in yield between progenies were demonstrated in each season. Consideration of the crop analysis data led to the conclusion that selection leads to the survival of the fittest population, and this is a mixture and not a pure type. Success in an attempt to breed a pure type better than the natural mixture will therefore have no necessary relation to the magnitude of the genetic variance available. It is suggested that the plant breeder should endeavour to retain as wide a range of material as possible in 'small bulks' trials to improve his chances of discovering some strains superior under all environmental conditions.

REFERENCES

Harland, S. C. (1936). *Biol. Rev.* **2,** 1.

Hutchinson, J. B. (1937). *Conf. of Sci. Workers on Cotton in India. I. C. C. C. Bombay Pl. Br. Paper*, No. 1.

Hutchinson, J. B. and Ghose, R. L. M. (1937, 1). *Ind. J. Agric. Sci.* **7,** 1.

——————————— (1937, 2). *Ind. J. Agric. Sci.* **7,** 233.

Hutchinson, J. B. and Kubersingh (1936). *Ind. J. Agric. Sci.* **6,** 672.

Hutchinson, J. B. and Panse, V. G. (1937). *Ind. J. Agric. Sci.* **7,** 531.

Sawhney, K. (1937). 'Hyderabad Cotton Survey Report' (In Press).

Snowden, J. D. (1936). 'The Cultivated Races of Sorghum'. Adlard & Son.

MILLING AND BAKING QUALITIES OF TWO NEW PUSA WHEATS

AN INTRODUCTORY NOTE

BY

B. P. PAL

Imperial Economic Botanist, New Delhi

(Received for publication on 20th December 1937)

QUALITY * in wheat is a relative term, depending on the purpose for which the grain or the flour is intended. Generally speaking, however, a high quality wheat is understood to be a wheat which is capable of yielding flour suitable for the production of good well-risen loaves of bread. Such wheats are usually known as 'strong' or 'hard' wheats, typical examples of these being the hard red spring wheats of North America which are in greatest demand for bread-making in Great Britain and which command the highest prices.

Indian wheats have the reputation of being soft and at one time the belief was current in the trade that India was incapable of producing strong wheats. A number of experiments carried out by the Howards with the co-operation of Dr. H. M. Leake and Dr. A. E. Humphries and, later, by Dr. F. J. F. Shaw with the co-operation of Dr. E. A. Fisher [Howard and Howard, 1908, 1910, 1911; Howard, Leake and Howard, 1910, 1913, 1914; Shaw, 1931] have however demonstrated conclusively that there exist Indian wheats which are equal in quality to good Manitoba wheat. In fact, many of the improved strains of wheat produced by the Botanical Section of the Imperial Agricultural Research Institute, and by some of the provincial departments of agriculture, are strong wheats. Although the formerly large exports of Indian wheats have almost ceased, the extension of the areas under these hard wheats appears to be desirable, as experience has indicated that these wheats are also preferred for consumption within the country in the form of *chapattis*. Accordingly the policy of the Imperial Agricultural Research Institute has been to subject the most promising strains of wheat evolved to adequate milling and baking tests, and to issue, for distribution, only those wheats which have been shown to possess satisfactory bread-making quality.

Among the wheats most recently bred at the Imperial Agricultural Research Institute, two strains, Pusa 120 and Pusa 165, were considered sufficiently promising to merit a test of their bread-making qualities. Pusa 120 was selected from the progeny of a cross between Pusa 52 and the Australian variety, Federation. It is a strong-strawed, high-yielding, bearded variety of medium maturity, and outstandingly resistant to the physiologic races of yellow rust occurring in India [Shaw and Pal, 1936]. Pusa 165 was obtained from a cross between Pusa 4 and Federation. This early-maturing, beardless wheat stands well, is a very high yielder and is very resistant to rust under field conditions. It possesses also a large grain of attractive appearance. The Imperial Council of Agricultural Research very kindly made the arrangements with the Research Association of British Flour Millers for conducting the tests and also met the expenditure incurred thereby. Along with samples of Pusa 120 and Pusa 165 grown at Pusa (non-irrigated conditions) and at Karnal (irrigated conditions) in 1935-36, Pusa 12 and Pusa 111 grown at Karnal in the same year, were also included as standards for comparison. The results of the tests are given in the Appendix.

---

* There is a considerable literature on quality in wheat and methods of determining it which it is not proposed to review here. A useful bibliography on this subject has been published by the Imperial Bureau of Plant Breeding and Genetics, Cambridge (Bibliography of Baking Quality Tests, 1934).

The importance of the several factors affecting the milling and baking quality, *e.g.*, colour, gas production, maltose content, diastatic activity, protein content, gluten quality, etc., has been discussed in a previous publication [Shaw, 1931]. Moreover the Report (Appendix) is so clear that further explanation is unnecessary.

Probably the most striking feature to be noted is the drop in the protein content as compared with the samples of Pusa 12 and Pusa 111 sent in 1930 [Shaw, 1931]. It is well known of course that the protein content varies from season to season and is influenced by soil, manuring, etc. An examination of the meteorological data however did not reveal any striking differences between the two crop seasons under consideration, except that in 1929-30 the rainfall during the cold weather (the season when wheat is normally grown in India) was lower than that for 1935-36. In the latter year the figures for humidity are slightly lower generally than in the year 1929-30. The composition of the grain grown at Karnal differs from that grown at Pusa and this may perhaps be attributed to the differences in the soil conditions in the two stations, together with the comparatively longer cold season at the former station.

The main purpose of the present tests was to determine the milling and baking quality of the two new wheats, Pusa 120 and Pusa 165. From this point of view, the results, taken as a whole, are satisfactory as they demonstrate that the hybrids are very near to Pusa 111 which has the reputation of being one of the highest quality wheats produced thus far in India. As the report states, the new wheats are " much superior to ordinary commercial Karachi wheat ".

REFERENCES

Howard, A. and Howard, G. L. C. (1908). *Agric. Res. Inst. Pusa Bull. No.* **14**, 11 pp.
——————— (1910). *Agric. Res. Inst. Pusa Bull. No.* **17**, 24 pp.
——————— (1911). *Agric. Res. Inst. Pusa Bull. No.* **22**, 31 pp.
Howard, A.; Leake, H. M. and Howard, G. L. C. (1910). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **3**, No. 4.
——————— (1913). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **5**, No. 2.
——————— (1914). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **6**, No. 8.
Shaw, F. J. F. (1931). *Ind. J. Agric. Sci.* **1**, 395-414.
Shaw F. J. F. and Pal, B. P. (1936). *Agric. and Livestock Ind.* **6**, 202-3.

Appendix

A REPORT ON SIX SAMPLES OF INDIAN WHEAT RECEIVED FROM THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA, DECEMBER, 1936

BY

E. A. FISHER, M.A., B.Sc. (Oxon.), D.Sc. (Lond.), F.I.C., F. Inst.P.
Director of Research, the Research Association of British Flour Millers

The samples were received in bags packed inside two tin-lined boxes. These tin linings were soldered and evidently meant to be sealed but several nails through the outside wooden box had pierced the tin. They had also been cut open evidently by the Customs authorities. This completely negatived an apparent attempt to keep the wheat samples at the moisture as grown although it must be admitted that the moisture contents were still very low.

The moisture and nitrogen contents, and also the bushel weight figures are given in the following tables.

Moisture and nitrogen contents and bushel weight figures on receipt

Wheat: Lab. Ref. No.	Sample No.	Moisture content	Total N	Total protein (N×5·7)	Bushel weight	
			Recalculated on a 15 per cent moisture basis		Dirty	Clean
		Per cent	Per cent	Per cent		
W 176	Pusa 12 (Karnal)	9·31	1·52	8·65	67·6	68·0
W 177	„ 111 „	8·75	1·86	10·57	68·5	69·3
W 178	„ 120 „	9·27	1·73	9·84	68·5	68·9
W 179	„ 165 „	8·63	1·85	10·55	68·5	68·8
W 180	„ 120 (Pusa)	9·85	2·04	11·61	65·0	65·2
W 181	„ 165 „	9·75	1·85	10·53	66·3	66·4

With the possible exception of Pusa 120 (Pusa) the protein contents of all the samples are very considerably lower than the general run of those examined in 1930. This appears to have important consequences and will be referred to later in this report.

The bushel weights are mostly quite high and are in keeping with the generally good milling qualities of these wheats.

Appearance of wheats

All the samples were white wheats. The Pusa samples were slightly less well filled and less bright than those grown at Karnal. They had a greyer, rather bleached, appearance compared with the latter, The sample Pusa 111 (grown at Karnal) differed considerably in appearance from that of the same variety grown in Pusa and examined by us in 1930. The present sample was plumper, much better filled and of brighter but less hard appearance, having a much paler colour. It contained an appreciable amount of starchy kernels and yellow-berry and its general appearance suggested much easier growing and ripening conditions than that of the older sample. These notes were made before the protein contents had been determined, and were of added interest when these were known. It will be noted that the present sample was over two per cent lower in protein than the old.

The difference was even more marked in the case of the variety Pusa 12. Here the present sample had markedly larger, plumper berries of paler and softer appearance than the sample of 1930.

The new variety, Pusa 120, was less uniform than the others in size and condition of berry. Much of it was rather small, prominently keeled but compact and well-filled grain. Most of the grain was vitreous and the sample fairly hard in appearance, but there was an appreciable amount of starchy grain and of yellow-berry.

Pusa 165 was uniformly rather long, large grain with rounded cheeks but hard and vitreous appearance.

CONDITIONING AND MILLING

The samples were very clean and really did not require cleaning. They were, however, passed through the cleaning plant to remove dust, etc., which was negligible in amount.

All the samples were conditioned by adding cold water in two doses with an interval of one day between the doses and then allowed to stand overnight. The amount of water given depended on the appearance of the wheat. The samples were milled on the 1st and 2nd January, 1937.

On the whole the wheats milled as would have been expected from their appearance Pusa 111 (Karnal) was outstandingly good although rather horny and resistant to reduction ; the bran was small and cleaned up well, and the wheat might advantageously have been conditioned to a rather higher moisture content. Pusa 120 (Karnal) behaved well ; Pusa 165 (Karnal) was fairly soft but otherwise satisfactory ; Pusa 120 (Pusa) was similar but rather softer than Pusa 165 grown at Karnal. The bran from Pusa 165 (Pusa) was the best of the set being clean and fairly large, but stocks generally tended to be rather softer than Pusa 120 (Pusa). Pusa 12 (Karnal) was outstanding giving soft starchy stocks.

The moisture contents of the mill feeds, *i.e.*, of the conditioned wheat and the 'Percentage Extraction of Flour' (calculated on 'Total Products') were as follow :

Our Ref. No.	Sample	Moisture content of mill feed 4 hrs., 120°C. electric oven	Extraction of flou
		Per cent	Per cent
W 176	Pusa 12 (Karnal)	15·51	63·5
W 177	,, 111 ,,	16·47	68·0
W 178	,, 120 ,,	16·58	64·5
W 179	,, 165 ,,	16·96	66·3
W 180	,, 120 (Pusa)	16·66	63·2
W 181	,, 165 ,,	16·66	64·4

These extractions are lower than those obtained in 1930, not because the wheats are at all lower in yielding power but because it is now preferred at these laboratories to work to a rather lower level of extraction. The fact that the extraction was materially higher in the case of Pusa 111 than the others does however reflect the particularly easy and excellent milling properties of this sample.

APPEARANCE OF FLOURS

Excepting two samples, the flours were of varying shades of yellow, Pusa 111 being the deepest. Pusa 165 (Karnal) slightly paler, Pusa 120 (Karnal) slightly paler still having a slightly greyish hue, and Pusa 165 (Pusa) palest of these four but still distinctly yellow.

Pusa 12 (Karnal) was outstanding. It had excellent colour being of a particularly clear, pale cream. It will be recalled that this variety gave flours of exceptionally good colour in 1930.

Pusa 120 (Pusa) was also outstanding but in a different way. Whereas the other samples were creamy or yellow, this was greyish white. In the flour this was not quite so pleasing but in the breadcrumb the effect was translated into an excellent bright whiteness, all the other samples appearing quite yellow by comparison.

Analytical results on flours

All results other than those for moisture-content have been recalculated on a fifteen per cent moisture-content basis.

Sample No.	Pusa 12 (Karnal)	Pusa 111 (Karnal)	Pusa 120 (Karnal)	Pusa 165 (Karnal)	Pusa 120 (Pusa)	Pusa 165 (Pusa)
Our reference number . .	W 176	W 177	W 178	W 179	W 180	W 181
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Moisture	13·52	15·17	15·11	14·35	14·19	14·45
Total nitrogen . . .	1·29	1·71	1·50	1·67	1·80	1·64
Total protein (N × 5·7) .	7·22	9·77	8·56	9·51	10·27	9·34
Dry gluten . . .	6·85	9·2	8·6	9·15	10·7	9·25
Soluble nitrogen . . .	0·220	0·230	0·208	0·237	0·235	0·223
Soluble extract . . .	4·65	5·15	5·59	5·19	5·11	4·99
Maltose figure . . .	1·1	1·9	2·1	2·1	1·9	2·0
Titratable acidity as per cent KH_2PO_4.	0·34	0·38	0·34	0·38	0·42	0·36
Ash	0·446	0·466	0·476	0·433	0·438	0·464
*p*H (10 per cent extract) .	5·95	6·05	6·14	6·04	6·11	6·12
Buffer value (10 per cent extract)	0·78	0·67	0·67	0·73	0·66	0·76

For notes on technique see report on wheats grown in 1929-30 [Shaw, 1931].

GLUTEN QUALITY

W 176.—Broke up a little at first. Moist gluten small in quantity, tough, with very good spring but very short.

W 177.—Washed out fairly well. Moist gluten tough with very good spring but short.

W 178.—Broke up a little at first. Moist gluten had medium body with fair spring and extensibility.

W 179.—Washed out fairly well. Moist gluten very similar to W 176 but greater in quantity.

W 180.—Washed out fairly well. Moist gluten bulky and soft with good extensibility but poor spring.

W 181.—Washed out well. Moist gluten had medium body with good spring but short.

The order of the protein contents is the same, of course, in the case of the flours as in that of the wheats. All are relatively low except perhaps Pusa 120 grown at Pusa, which alone just comes within the range of protein content expected in a bread-making flour. The ash figures would all be called low for flours from wheats of eastern origin.

The figure for soluble extract is perhaps a little high in the case of Pusa 120 grown at Karnal, but otherwise these figures and those for soluble nitrogen, titratable acidity, *p*H and buffer values, and maltose appear to be normal, and ordinarily would be interpreted as implying soundness of grain.

GAS PRODUCTION

In each test the following amounts of material were used: 50 grms. flour, 1 grm. (=2 per cent of weight of flour) of yeast, 0·625 grm. (=1¼ per cent) salt and 30 c. c. of water.

Gas-production figures in c. c. are given below together with (for purposes of comparison) those of a control flour which was a commercial straight run flour from a mixed grist.

Our Ref. No.	W 176	W 177	W 178	W 179	W 180	W 181	Control
Hours							
1st	63	55	53	56	50	55	60
2nd	89	81	87	87	90	85	95
3rd	86	89	90	85	104	84	105
4th	44	75	75	77	106	84	105
5th	28	75	75	68	87	79	61
6th	20	62	63	63	53	63	44
7th	18	49	54	54	32	42	40
8th	14	41	46	40	18	38	33
Total 24 hours	495	765	840	772	830	730	822

COMMENTS ON GASSING FIGURES

Pusa 12 is the only sample whose gassing power definitely falls short of the ordinary requirements for a bread-making flour. The other samples are all fairly satisfactory in this respect and should be capable of gassing sufficiently even if baked unblended and without any enrichment of the dough. In our baking tests, two per cent sugar was incorporated into all doughs to make certain that no comparisons were invalidated in this respect.

BAKING TESTS

Each sample was baked unblended at each of three different absorptions, *viz.*, 15, 15½ and 16 galls. per sack, in each case using a total fermentation time at 80 F., including final proof, of 3¼ hours, with two per cent yeast and 1¼ per cent salt.

At dough making Pusa 12 (Karnal) was distinctly less tough than the other samples and clearly had about one gallon per sack lower absorption. Pusa 120 (Pusa) was slightly less tough than the remainder (excepting Pusa 12), but as a whole these samples were of tight body even at sixteen gallons per sack and were rather short.

They all responded similarly and satisfactorily to fermentation.

In the bread Pusa 12 and Pusa 111 were each distinct from the rest.

Pusa 12 had fairly good volume but biscuity crust and 'scabby' sides, with rather coarse irregularly grained crumb. This crumb appeared yellowest of all the samples.

Pusa 111 gave rather smooth loaves which had a 'bound' under-developed appearance, with rubbery crumb of very close grain.

Pusa 120 (Karnal), Pusa 165 (Karnal) and Pusa 165 (Pusa) were much alike and had only very fair volume though they were better in this respect than Pusa 111. They had rather poor face and broken crust, but fairly good all-round crumb.

Pusa 120 (Pusa) was easily the best bread baked under these conditions. It appeared relatively well developed and it was particularly outstanding in that its crumb was a very good white, whereas all the others were more or less yellowish. It also seemed most responsive to the effect of varying amounts of water used in dough-making in the sense that the largest amount tried gave the best results, Pusa 12 being next in this respect (but here the lower amount gave best bread) whereas the other samples were very little affected through the variations tried. The only defects of the bread of Pusa 120 (Pusa) were a flintiness of crust and tenderness of crumb.

The samples were then each baked unblended using a total fermentation time of 4¾ hours, and a water absorption in each case of sixteen gallons per sack, except Pusa 12 which was given fifteen gallons.

All the samples worked satisfactorily up to scaling and all, except Pusa 12 and Pusa 120 (Pusa) which were slightly tender, were tight but rather short when moulded.

The bread of Pusa 111 still looked underdeveloped being rather small with a rather close-grained rubbery crumb. Pusa 120 (Karnal), Pusa 165 (Karnal) and Pusa 165 (Pusa) were not very dissimilar to Pusa 111 but rather less small and bound in appearance.

Pusa 12 had good volume and good soft crumb, but a 'flying' top and ragged outside appearance.

Pusa 120 (Pusa) still had the largest volume and best developed appearance, with good soft crumb, but with a 'flying' top and 'scabby' sides.

BLENDING TESTS

In the first place each sample was blended to the extent of fifty per cent with an all-English flour of average quality for this type. This is a severe test, applicable to flours of definitely strong type like Manitoba. A strong flour like a good Manitoba should be able to 'carry' fifty per cent of a weak flour such as average English and give a satisfactory all-round commercial loaf. In the present tests such a blend of the English flour used with a good Manitoba flour was included for the purpose of comparison, as were also two samples of good quality London flours, and each sample was given liquor at the rate of sixteen gallons per sack.

At dough-making the Manitoba blend and the two London flours were of good body with good spring and extensibility. The blend of Pusa 12 was tender, with very fair spring and extensibility. That of Pusa 120 (Pusa) was of fair body with fair spring and extensibility. The remainder were of fairly good body with fairly good spring and extensibility. All samples rose and worked well throughout fermentation and retained the above differences.

The Manitoba blend and the two London flours gave loaves of good all-round quality.

Of the Indian samples Pusa 111 and Pusa 165 (Karnal) gave the best blended loaves which were of good volume, face and outside appearance, with fairly close-grained rather honeycomb, crust of good spring, pile and texture. Pusa 165 (Pusa) was slightly poorer in volume but otherwise not inferior to these samples. Pusa 120 (Karnal) had rather poorer crumb. It was of good volume, but with a tendency to broken face, and crumb with rather open and irregular grain, fairly good spring, good pile and texture. Pusa 120 (Pusa) was rather poorer still. It had good volume but broken face and 'flying' top with rather open-grained, very soft crumb of the honeycomb type, of good pile and texture, but only fair spring.

Pusa 12 gave distinctly the poorest blend. It was smaller than the above with broken face, 'flying' top and inferior crumb to the other samples.

Secondly, each sample was blended to the extent of twenty per cent with a good London flour to give an idea of its suitability for use as a 'filler' wheat. A wheat may be not strong enough to take the place of Manitoba and yet may be itself of quality fit for bread-making purposes in the unblended state, so that like Plate wheat, it is useful for incorporating in quite large amounts into otherwise well-balanced grists. Such a wheat should not produce any deterioration whatever when added to the extent of, say, twenty per cent to a good flour. The results on the present samples were satisfactory in this respect. None of the Indian flours made any appreciable difference in dough or loaf to the London flour.

CONCLUSIONS

In some respects the results of the present tests had disappointing and unsatisfactory features. Regarded from the point of view of strength, Pusa 111 appeared to have the greatest potentialities, yet it was very much poorer than the sample of the same variety grown at Pusa examined in 1930. On that occasion the wheat exhibited the important characteristics of a good Manitoba. The present sample appeared to tend in this direction but it did not seem possible to bring out its potentialities sufficiently in the bake-house.

In this connection it should not be lost sight of that these wheat varieties may be very susceptible as regards baking quality to cultural conditions during growing and ripening. In 1930 Pusa 111 grown at Sind was much inferior to that grown at Pusa. In the present case the divergence of conditions appears to have been much greater, as reflected in the different appearance of the wheat, and protein content lower by over two per cent.

Protein content, with some varieties particularly, may have marked importance as a factor additional to protein quality. In examining wheats from other eastern or near-eastern countries we have had more than once to point out that a newly bred strain would have no chance of developing to advantage in the bake-house the qualities which might appear to be inherent in it, unless the protein content could be raised, through appropriate cultural or manurial treatment, appreciably above the distinctly low level which is frequently found in such crops. Seasonal variations in climatic conditions are also of immense importance in determining variations in quality.

Some of the other samples also appeared to have some potentialities as strong wheats though not to the extent of Pusa 111. Again, the same remarks as to protein content might apply. Pusa 12 was distinctly weaker than all the others. It had, particularly, distinctly lower water absorption in the bake-house, and was definitely not in the 'strong' wheat class. All the samples, however, including Pusa 12, had distinct value as 'filler' wheats, for blending purposes, and were much superior to ordinary commercial Karachi wheat in this respect. Judged from this point of view solely and not from that of a strong wheat the sample of Pusa 120 grown at Pusa in some respects showed up to best advantage. It should perhaps be pointed out that this sample had the highest protein content and was the most nearly satisfactory of all the samples in this respect.

MICRO-CLIMATOLOGY OF AN IRRIGATED COTTON FIELD IN SIND

BY

B. M. DABRAL, M.Sc.

AND

S. S. CHINEY, B.Sc.

Agricultural Research Station, Sakrand (Sind)

(Received for publication on 21st July 1937)

(With Plate VII and fourteen text-figures)

CONTENTS

		Page
I.	Introductory	161
II.	Method of observations and agricultural details	162
III.	Results	163
IV.	Discussion of results	181
V.	Summary	183
VI.	Acknowledgments	184
	References	184

INTRODUCTORY

In arid tracts, the study of local climate in the open as well as inside a crop is of great importance. Irrigation not only supplies water to the plants but also modifies the immediate environment of the crop. The difference between the two is not constant; since, as the moisture in the soil goes on diminishing after irrigation, its effect on the temperature and humidity conditions inside the crop is also lessened. After another watering, a new environment again sets in. Any correlation between outside and inside conditions would therefore not hold good for more than a short time. It is thus not only the standing crop but also the periodicity and intensity of irrigation that brings about characteristic differences in the climate inside and outside the crop.

The present paper deals with observations carried out at Sakrand in the cotton crop during the *kharif* season (May to October) of 1935. The points of study were mainly, the finding out of the differences in temperature and relative humidity between irrigated and unirrigated conditions at a few selected heights above the ground and the deviations from the values obtained from instruments exposed at four feet height in the Stevenson Screen on the meteorological office pattern.

II. METHOD OF OBSERVATIONS AND AGRICULTURAL DETAILS

The importance of simultaneous recording of the different atmospheric factors along with measurement of crop growth was realised early in our studies of crop physiology. Standard instruments for measuring temperatures, humidity, wind velocity, evaporation, etc. were exposed in an observatory situated amidst the experimental plots (Plate VII). Fig. 1 gives diagrammatically the position of the observatory in respect of the experimental area and the exposure of the instruments.

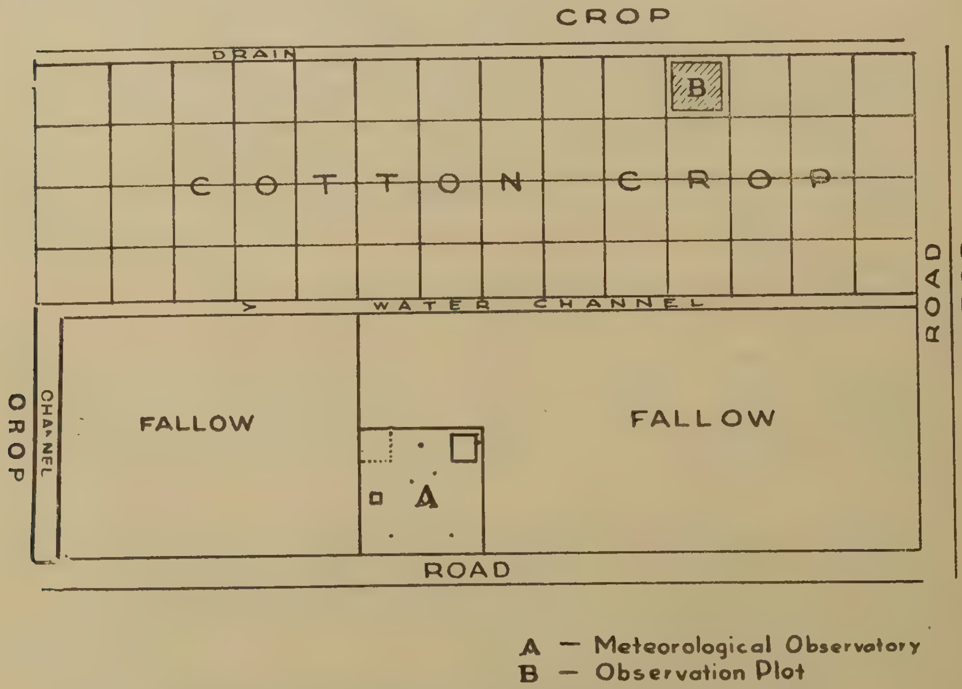
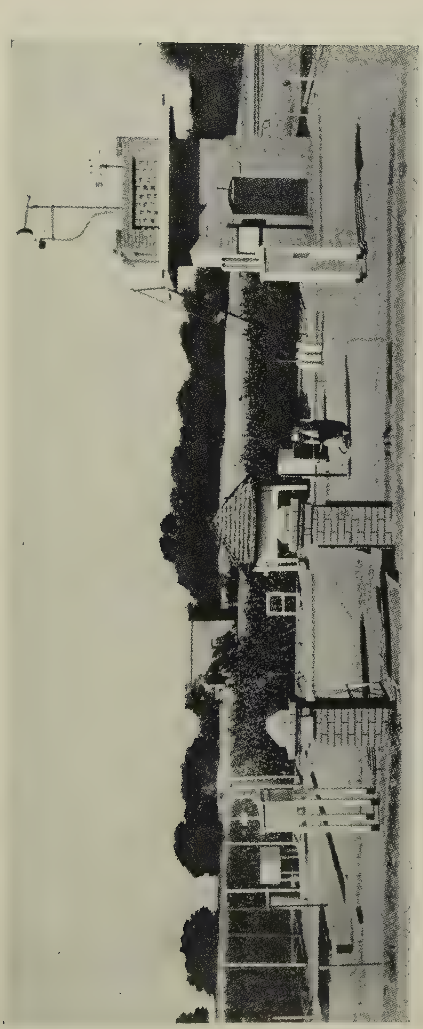


FIG. 1. Position of the observatory in respect of the experimental area.

Dry-and-wet-bulb temperatures were recorded with the help of an aspirated Assmann psychrometer (R. Fuess) small pattern, as recommended by Ramdas, Kalamkar and Gadre [1934]. The instrument was frequently compared with the other standardised instruments in the Stevenson Screen.

Observations were taken (1) in the morning (sunrise for the locality) and (2) in the afternoon at 16-00 hours I.S.T. The time for morning observations was changed fortnightly according to the local time of sunrise. This time corresponds to the minimum temperature epoch. In the afternoon the time was fixed at 16-00 hours according to the clock. Previous records showed that during the *kharif* season the maximum temperatures were reached by this hour. It corresponds more or less to the maximum temperature epoch for the day. Observations were recorded in the same order every day and did not take more than half an hour to complete. The micro-climatic ob-

PLATE VII



Meteorological observatory amidst the experimental plots

servations were started just after the first irrigation after sowing, when the crop was about half a foot above the ground, and were continued throughout the season.

Soil temperatures were recorded with the help of two Baird and Tatlock hot-bed-thermometers inserted in the soil in the cropped and fallow plots so that the bulbs were exposed at six-inch horizon below the ground. The stem and the exposed parts of the thermometers were protected from direct sun by narrow wooden cases opening on the northern side only.

The variety of cotton under which the micro-climatic records were taken was 'Sind Sudhar' a selected strain of 289F from the Punjab-American group. It is a bushy mono-podial type and though grown at three feet distance, leaves no gap between rows, once its maximum vegetative growth is attained (2 to 2½ months after sowing). In the beginning, observations inside the crop were taken in two different beds receiving similar treatments, but as they did not show significant differences, they were restricted to only one bed. Irrigation was given on the basis of 100 duty, *i.e.* one cusec for 100 acres of cotton crop. This came to a constant rate of about four inches every twenty days. The soil was of a loamy type so that there was no free water standing under the crop after irrigation. A preliminary soaking dose of eight inches was given in two instalments on 18th and 20th June. Seeds were sown on 23rd and 25th of May. After about five days most of them had germinated fully. First water after sowing was given on 21st June, *i.e.* four weeks after the sowing date. The land was hoed by hand on its coming in condition after almost each irrigation. The area of the experimental bed was 1/40th of an acre and the average density was five plants per square yard. The plot was well filled.

III. RESULTS

A. *First period of crop growth* (*22nd June to 9th July*) (*early growth phase*)

The average height of plants was about six inches at the beginning of this period and about one foot at the end. This was the first phase of growth when differentiation of tissue went on at a slow but progressively rising rate. Daily observations on temperature and relative humidity (calculated from dry-and-wet bulb figures) taken between two irrigations (21st June and 11th July) constituting this period, are given in the form of graphs for both the minimum and maximum temperature epochs.

The general weather during this period was fair. Wind velocity was very high with an average of about seven miles per hour. Evaporation from a free water surface (in a large metallic tank) occasionally approached the high value of one inch per day. The mean duration of bright sunshine during the period was about twelve hours while on a few days it was eight to ten hours.

(*1*) *Morning observations* (*minimum temperature epoch*).—The daily minimum temperatures are plotted in Fig. 2. Comparing the air temperatures, it is seen that the effect of the irrigated crop cover is quite significant at six inches above ground but decreases rapidly with height. The height of plants also was about six inches during this period. The deviation of the crop climate from that of the open lasts for about a week after irrigation, after which the outside and inside temperatures are more or less similar. Day-to-day variations, however, run parallel to the values obtained under screen conditions at four-feet height.

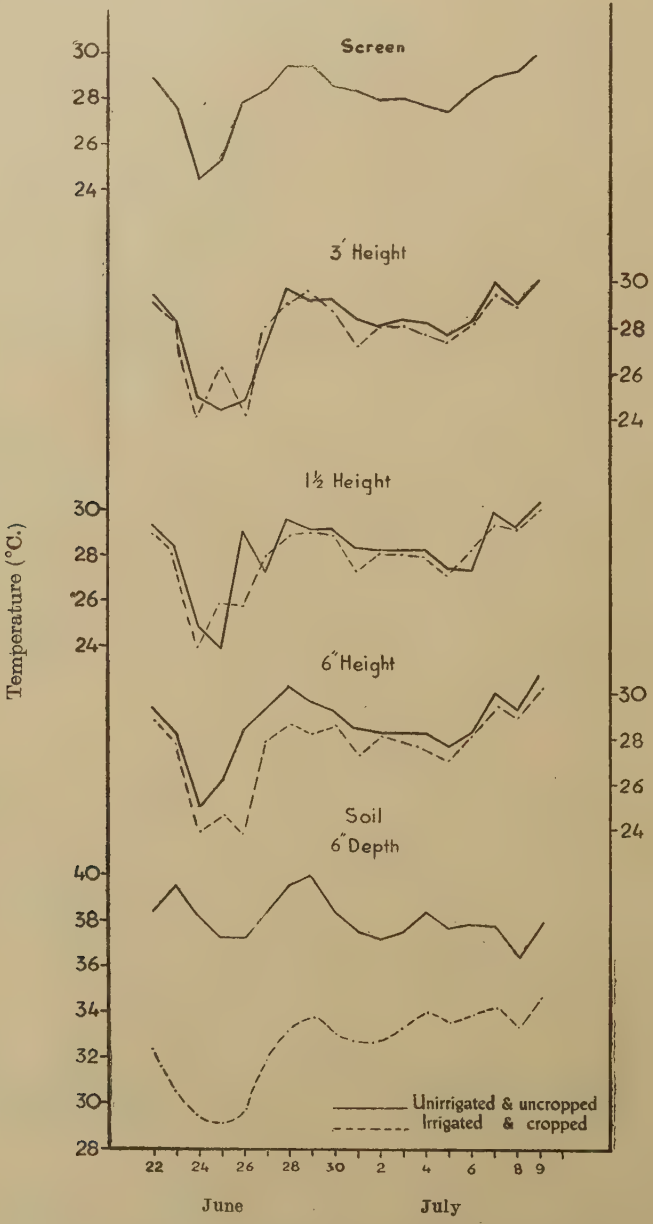


FIG. 2. Daily minimum temperatures (first period)

Soil temperatures at six-inch layer under ground show very wide differences between irrigated and fallow areas. The difference is very high soon after irrigation, but it goes on diminishing as the soil gets drier.

Relative humidity (Fig. 3) in the morning is generally high both inside and outside the crop. The cropped areas show a higher percentage up to about ten days after irrigation. The daily trend is however similar to that of the observations from the screen.

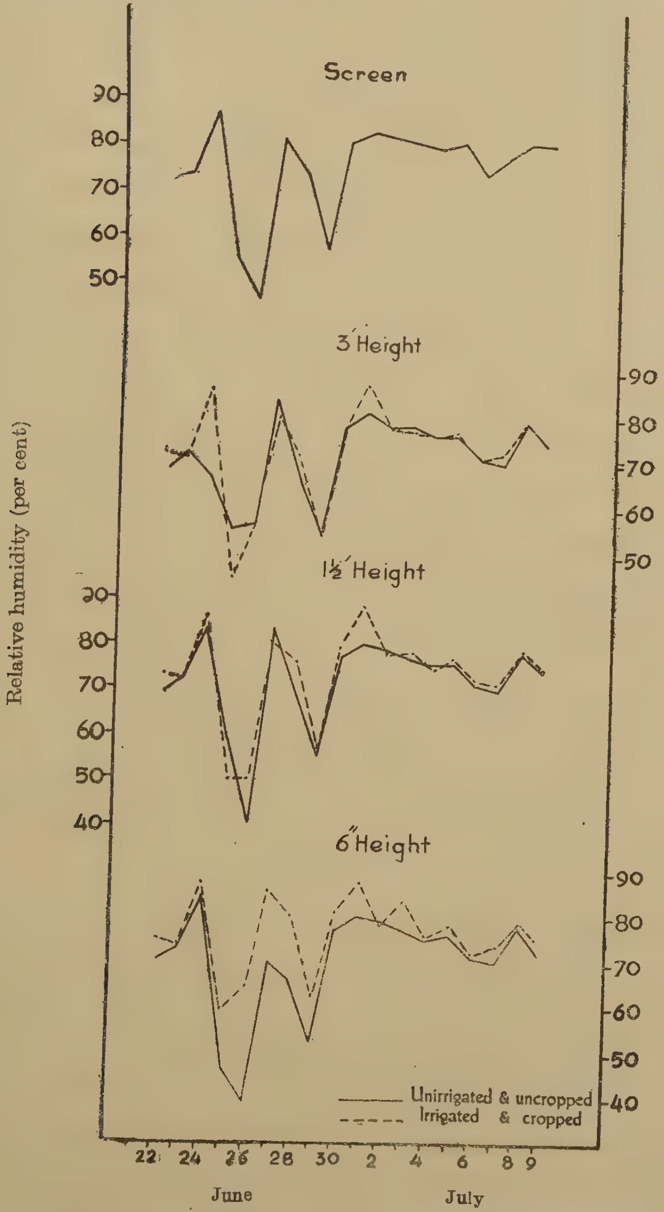


FIG. 3. Relative humidity in the morning (first period)

(2) *Afternoon observations* (*maximum temperature epoch*).—Fig. 4 gives the daily records of temperature taken at 16-00 hours in the afternoon. The effect of crop and irrigation is much more marked at this hour than in the morning. The air temperatures at six-inch layers above the cropped bed are comparatively lower than those over barren ground and the two show wider differences now than in the morning. At this hour even the temperatures at 1½-ft. and 3-ft. levels above ground show differences. The vertical rise of water vapour due to evaporation from the soil and transpiration from the plants is responsible for modifying the temperatures at these levels over the cropped bed. The general trend of air temperatures inside the crop from day to day is to follow the variation observed in the screen with a superimposed tendency to rise progressively after the date of irrigation. Thus the widest difference between the temperatures inside and outside the crop are observed for about three days after irrigation. Soil temperatures show the same tendencies as observed in the morning. There is a clear difference of about eight degrees centigrade between irrigated and fallow land for some time after irrigation. After about a week, the temperature in the irrigated plot begins to rise and approaches that of the open by the next irrigation. On July 7th, the sky was overcast with clouds. Its influence in bringing down air temperatures and minimising the difference between the two environments can be seen very well.

Relative humidity (Fig. 5) at this hour is very low in all cases. The cropped area shows some increase at the six-inch height above ground. The other layers do not show much of a difference. The day-to-day variations in all cases follow the trend seen under screen condition, the widest differences being those observed for the first two or three days after irrigation.

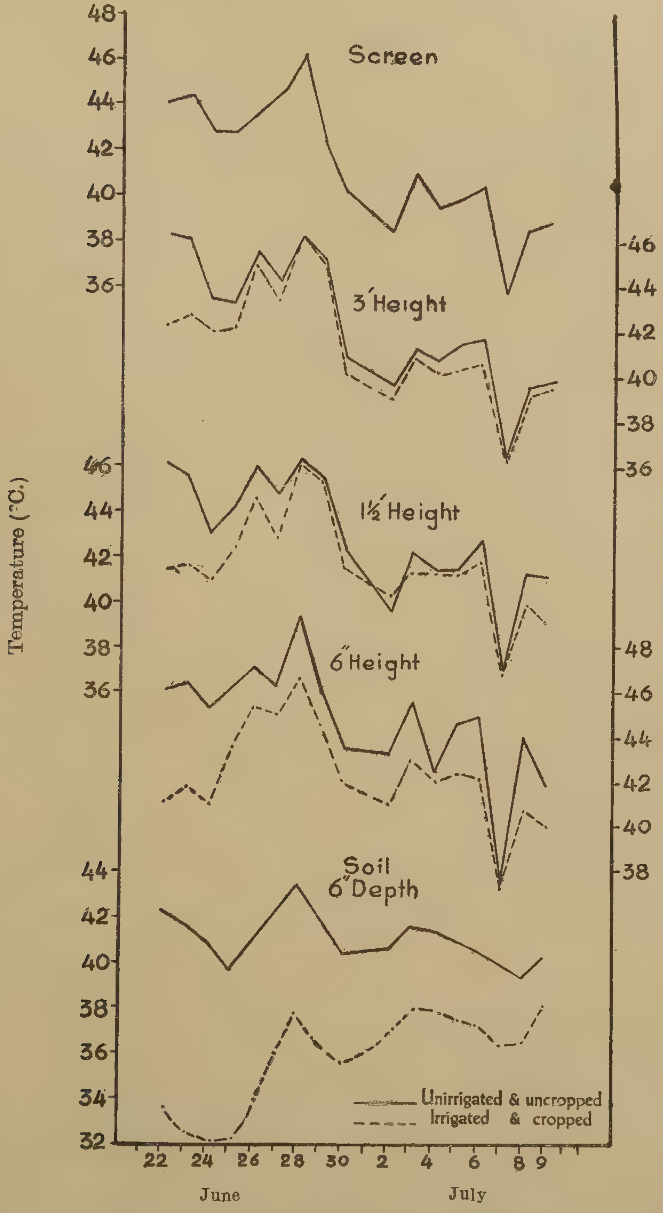


Fig. 4. Maximum temperature (first period)

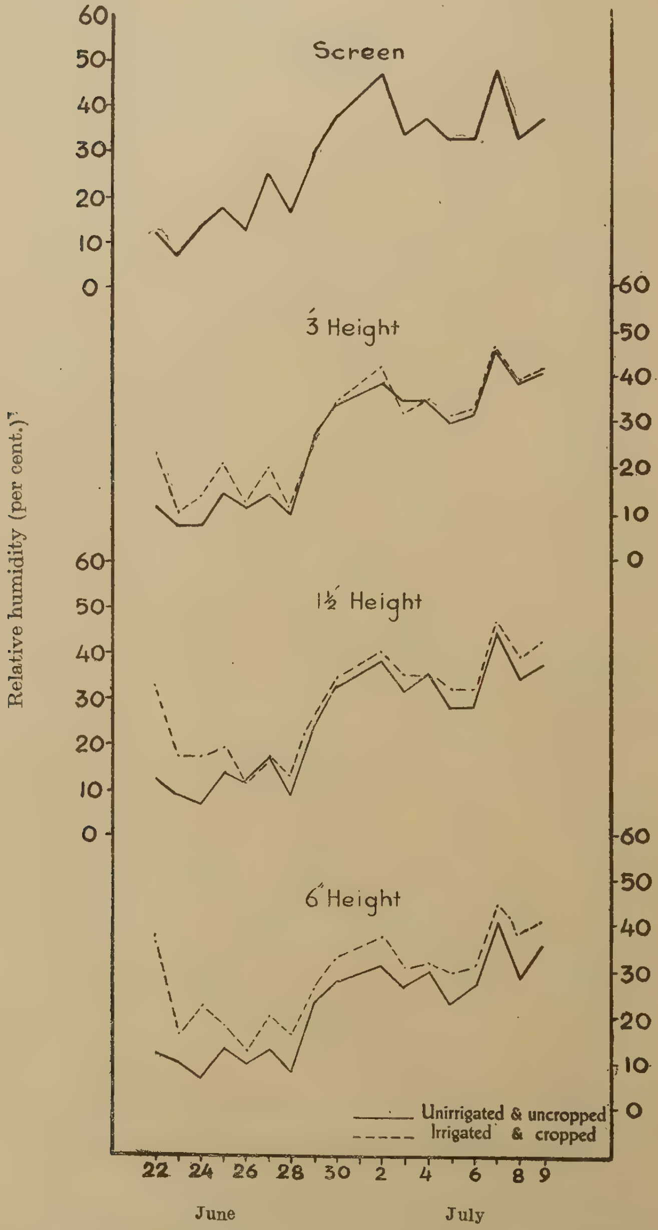


FIG. 5. Relative humidity at 16-00 hours (first period)

B. Second period of crop growth (31st July to 18th August) (maximum vegetative phase)

During this period the crop was growing at its maximum rate. The average height of plants was 1½ ft. in the beginning and about 3 ft. at the end. Along with the main axis all the main branches were also growing vigorously. Fruiting shoots and flower-buds were developing fast.

The weather during the period was characterised by general lowering of temperatures and rise in relative humidity. Out of twenty days, three were intensely cloudy having only half to one hour of sunshine during the day. The average hours of sunshine on most of the other days was about ten to eleven. Wind velocity specially during the day had also decreased to about four miles an hour on an average throughout the twenty-four hours. Evaporation had decreased to about 0·6 in. per day.

(*1*) *Morning observation (minimum temperature epoch)*.—Fig. 6 gives the daily temperatures for the period under the various conditions. The temperatures inside the crop, however, are less depressed than in the previous period. The cropped and exposed areas do not exhibit as much differences among themselves at this hour as during the first period, in spite of the fact that the crop has now grown considerably and has covered almost the whole of the plot. This shows that the effect of irrigation and cropping is to keep the inside environment warmer when outside temperatures are falling. The curves show that on many days when outside temperature had fallen below 25°C., the cropped bed shows higher values. The day-to-day variations follow those of the screen and there is a very close correlation between all values.

Soil temperatures show again a very wide difference between the two conditions. The temperatures in the irrigated bed go on falling till about five to six days after irrigation, after which they rise slowly and tend to come nearer the temperature in the fallow bed.

Relative humidity (Fig. 7) everywhere is higher during this period and probably for this reason does not show wide variation between the two places. At six-inch height above ground the effect of irrigation in raising the relative humidity is seen up to about ten days after the date of watering. Later on, there is no difference, the fluctuation depending on that of temperature.

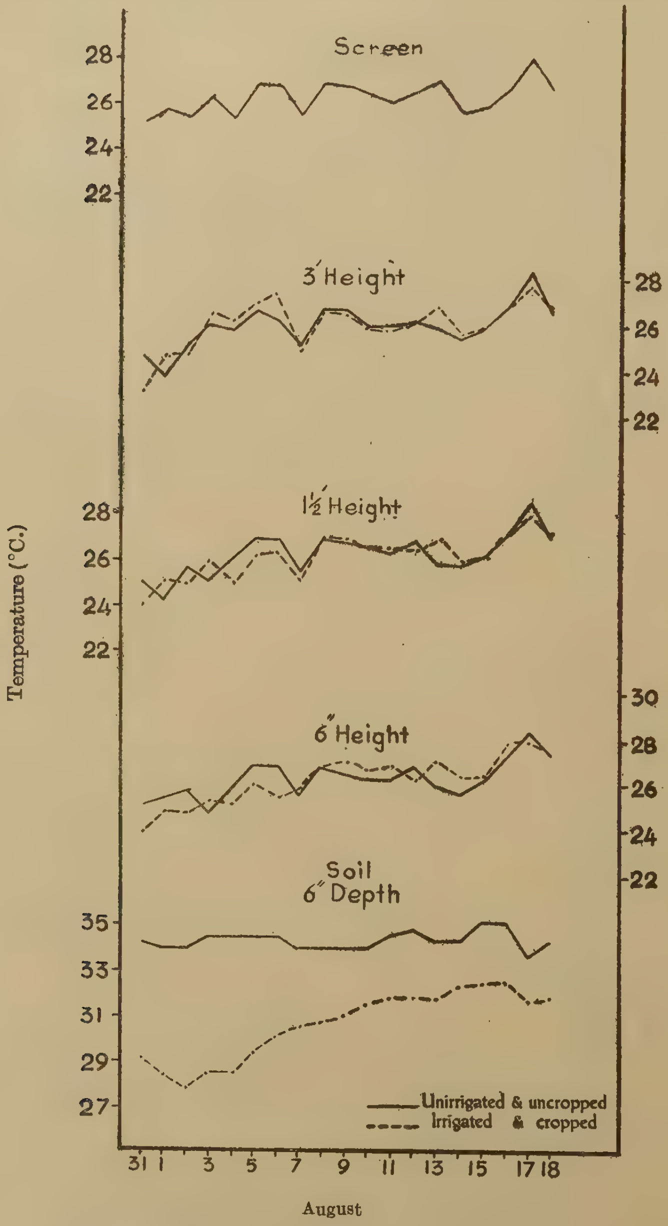


FIG. 6. Morning temperatures (second period)

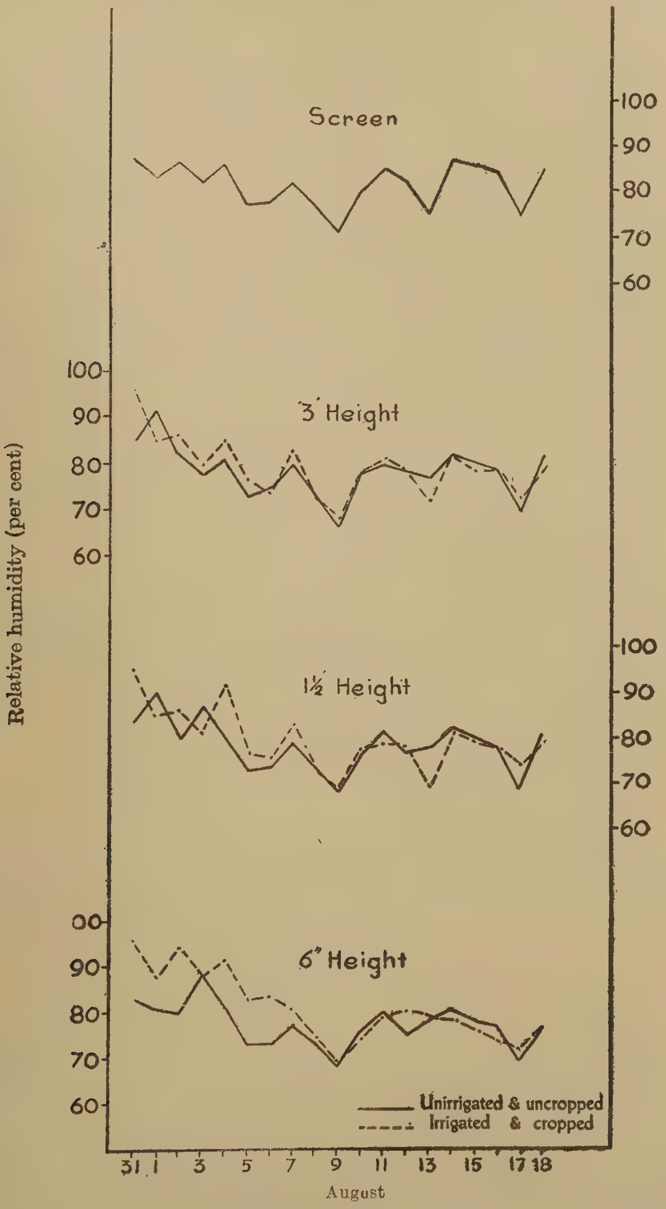


FIG. 7. Relative humidity in the morning (second period)

(2) *Afternoon observations* (*maximum temperature epoch*).—The daily temperatures observed under the different situations are given in Fig. 8. The effect of irrigation and crop is very prominently brought out by the graph. The temperatures recorded in the screen show almost constant values from 31st July to 8th August. The 3-ft. and $1\frac{1}{2}$-ft. layers of air above barren soil also follow the screen though the values are higher. At six inches the temperatures show independent variations which may be explained as being due to local convection currents in the afternoon. The cropped area however follows an altogether different course. On the days immediately after irrigation, temperatures vary greatly. The widest differences are seen in the lowermost layer. The general tendency of the temperature inside the crop is to rise progressively and come nearer to outside values. Thus from 9th August when the inside temperatures have come as near outside values, as possible, there is a greater correspondence between the daily variations observed under all situations. On the 16th and 17th of August when the sky was overcast with clouds the temperatures everywhere were equal.

The soil temperatures follow tendencies similar to those in the morning. The lowest values are seen five to six days after irrigation ; later, there is a gradual rise.

The values of relative humidity at this hour (Fig. 9) show similar differences. The irrigated and cropped bed always shows higher percentage of moisture in the air than the fallow. The difference goes on lessening as the height above the crop is increased. The differences are great up to five to six days after irrigation, after which they begin to decrease gradually up to the 10th August. Later on, the daily variations run almost parallel in all situations.

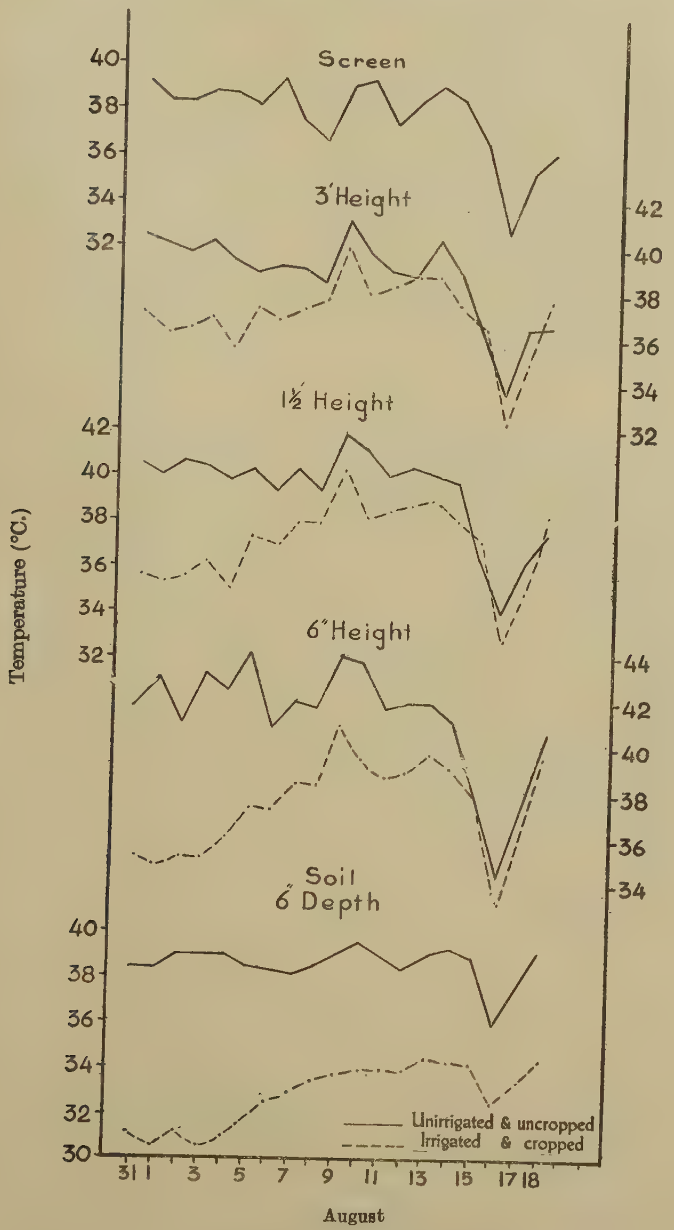


FIG. 8. Afternoon temperatures (second period)

H

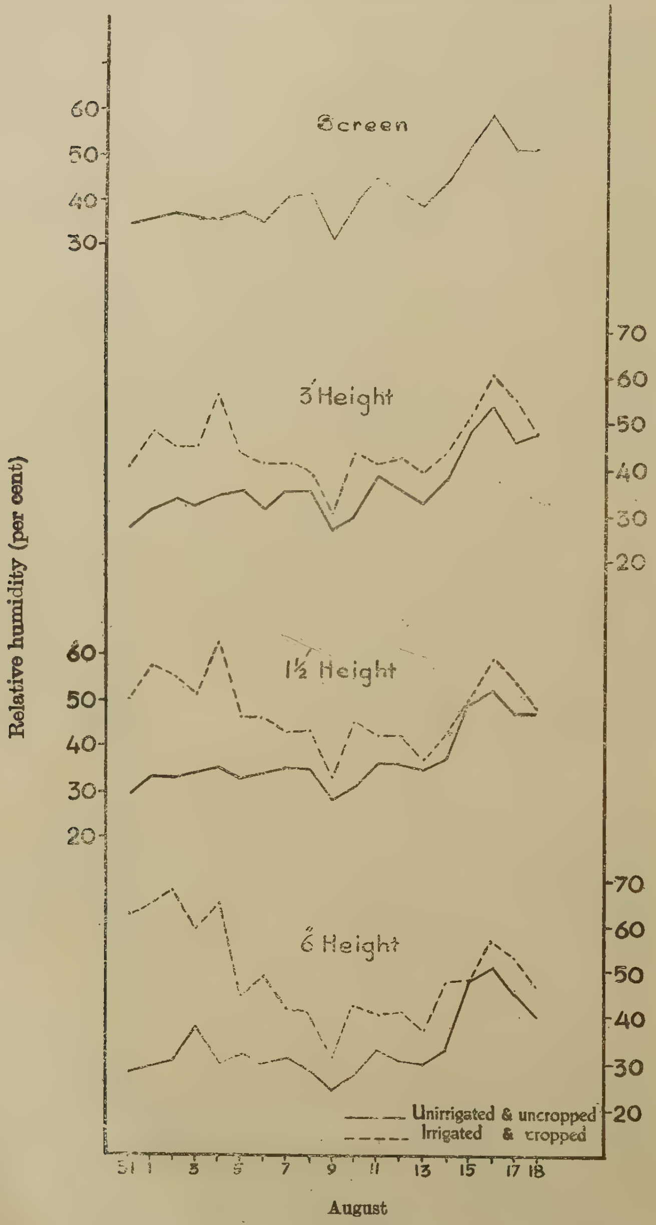


FIG. 9. Relative humidity at afternoon (second period)

C. *Third period of crop growth (9th to 29th September) (reproductive phase)*

During this period vegetative development of the plant had attained its maximum value. The plant showed an average height of 3¼ ft. to 3½ ft. above ground. Irrigation was given on the 8th September and repeated on the 30th September. General weather was fair with no cloudy days, the average hours of sunshine being ten. Air movement was small, of the order of about two to three miles per hour. Evaporation was going on at the rate of about 0·4 in. per day. In short, the general conditions were comparatively mild.

(*1*) *Morning observations* (*minimum temperature epoch*).—Fig. 10 gives temperatures recorded in the various situations during this period. The cropped area showed equal temperatures at 1½-ft. and 3-ft. layer but higher values at six-inch height. There was a general rise of temperatures from 11th to 17th September in the exposed conditions. The cropped bed tended to follow suit but did not go as high as outside. During the second half of the period the differences between the two sets of conditions are not greater. As in the second phase in August, the temperatures over cropped beds do not fall to the same extent as in the open.

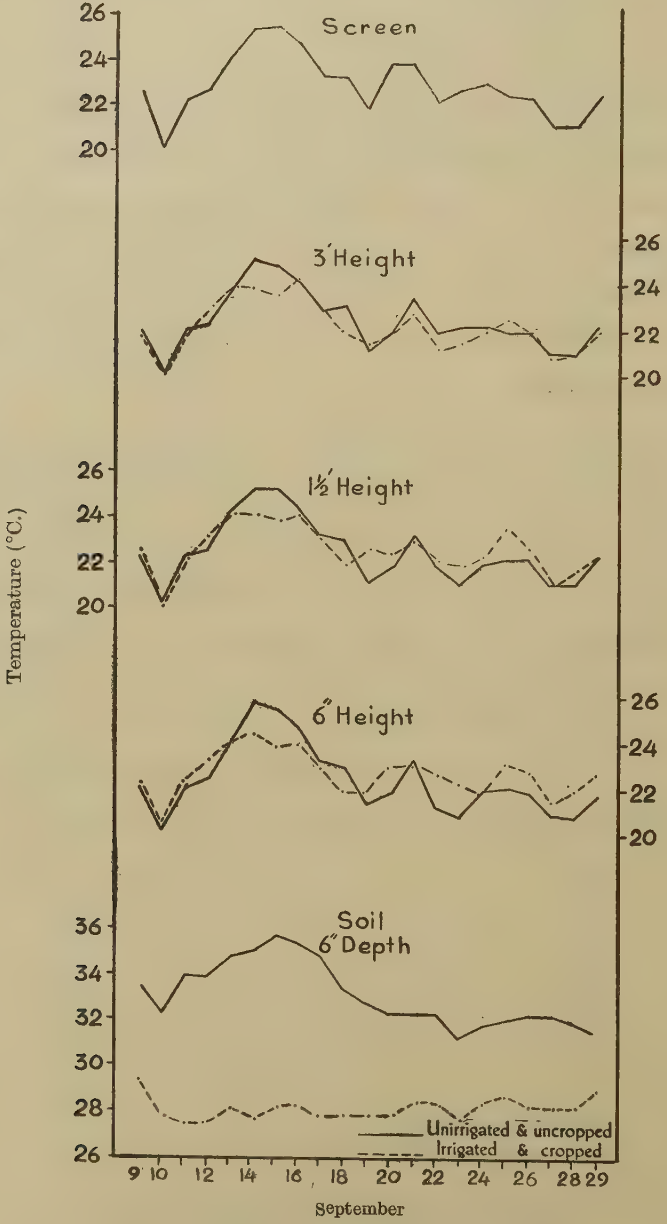


FIG. 10. Morning temperature (third period)

Thesoil temperatures show, as usual, very wide differences; the lowest is attained four to five days after irrigation. This time, the tendency of the soil temperatures in the cropped bed to rise later on is not so prominent.

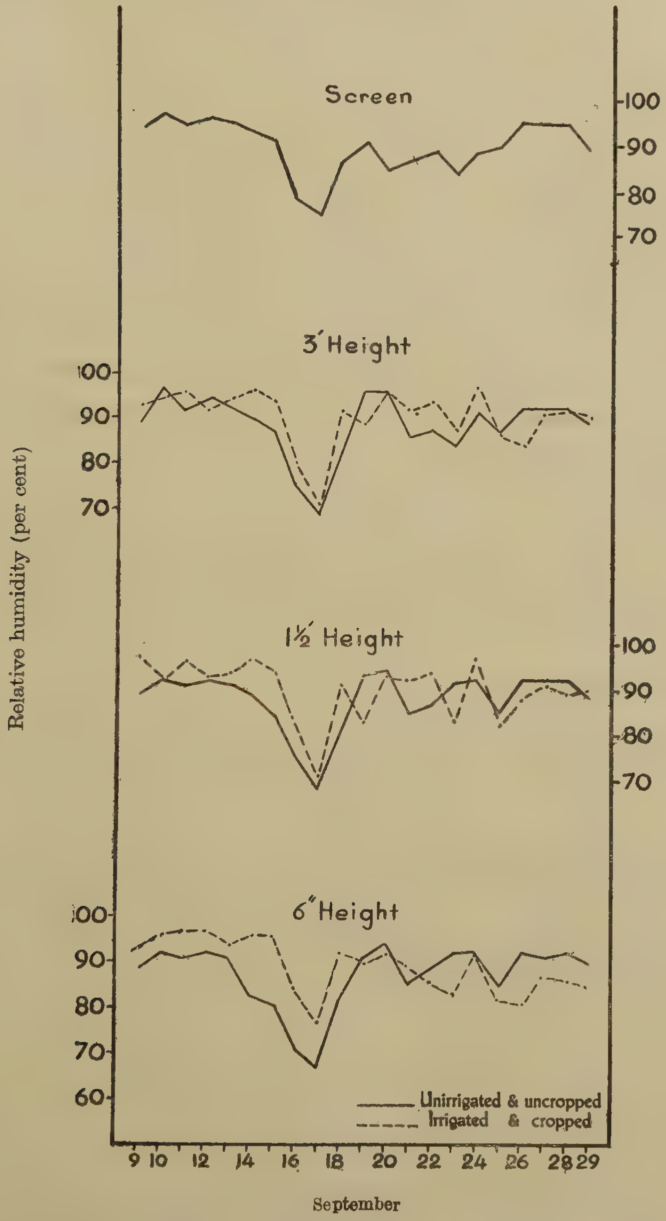


FIG. 11. Relative humidity in the morning (third period)

Relative humidity (Fig. 11) is as usual very high and follows similar trends from day to day in all localities. In the lower strata of air, the differences between the cropped and uncropped areas remain prominent till about ten days after watering, after which they tend to diminish.

(2) *Afternoon observations* (*maximum temperature epoch*).—Fig. 12 shows the daily values of temperatures in the various situations. As in the second phase, the afternoon values show very wide differences due to irrigating and cropping. On looking at the screen figures, the period can be divided in two halves. The first period, showing high maximum temperatures, lasts from 9th to 18th September and the second of low temperature from 19th to 29th. The general trend of the curve in the cropped plots is to show wide departures from outside value for a few days after irrigation and then slowly to rise and come near to them. The lower layers are wider apart in their temperature conditions than the higher ones. The rapid and sudden fall of temperatures inside the cropped area, on the 19th and 24th of September, seems to be due to some mistake in the exposure of the instruments. It is probable that the dry bulb was wetted by some chance spilling from the wet bulb tank. A study of anemograph and thermograph charts did not reveal any special features leading to a drop in temperature at this time.

Soil temperatures inside cropped beds again show great deviations from those outside. The minimum is reached about four to five days after irrigation. The tendency to rise is not so prominent at this time as in earlier months.

Relative humidity (Fig. 13) is almost always higher in the cropped bed than over the fallow. The difference gets lessened as the height is increased. The six-inch and 1½-ft. layer shows the usual downward curve reaching towards outside values up to the 18th September.

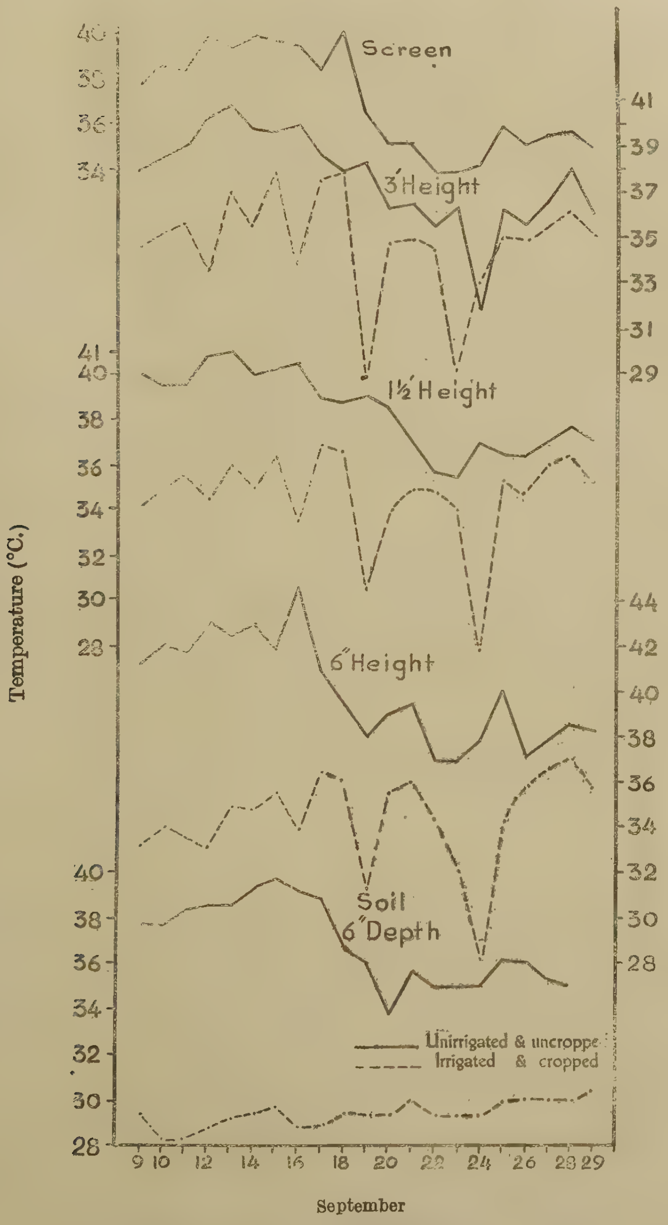


FIG. 12. Afternoon temperature (third period)

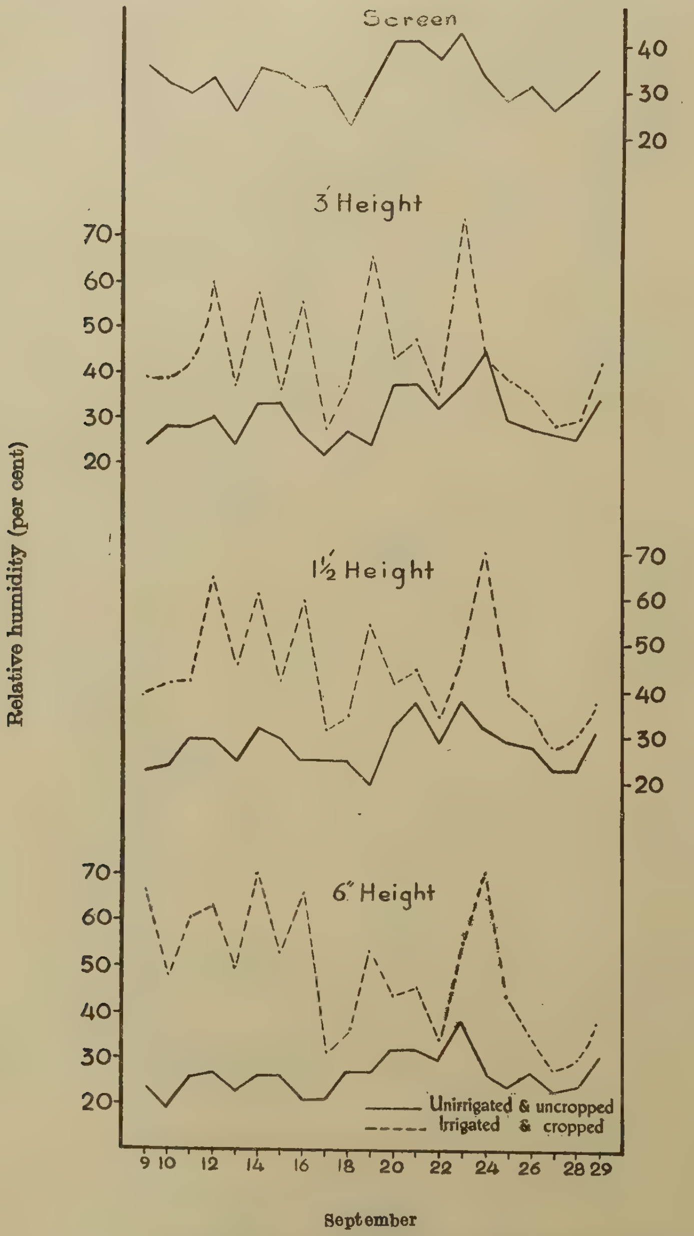


FIG. 13. Relative humidity in the afternoon (third period)

IV. DISCUSSION OF RESULTS

Air temperatures

The differences in morning temperatures recorded in the different situations can be considered as differences in the minimum values and those in the afternoon as in the maximum figures.

The temperatures inside the cropped area are guided by three independent factors. (1) The most dominating factor is the general air temperature as revealed by screen values. The day-to-day fluctuations observed here travel to all local situations and give the basic seasonal drift. (2) The effect of irrigation is to implant upon it a periodicity depending upon the intervals between two waterings (Fig. 14). The widest variation from the outside temperatures are seen just after irrigation which gets lessened as the time for the next irrigation approaches near. The widening and narrowing of space between the temperature curves of cropped and uncropped beds is characteristic of all heights above the ground level. (3) The density of crop brings in shade which acts like clouds in effective changes in the environment of the crop.

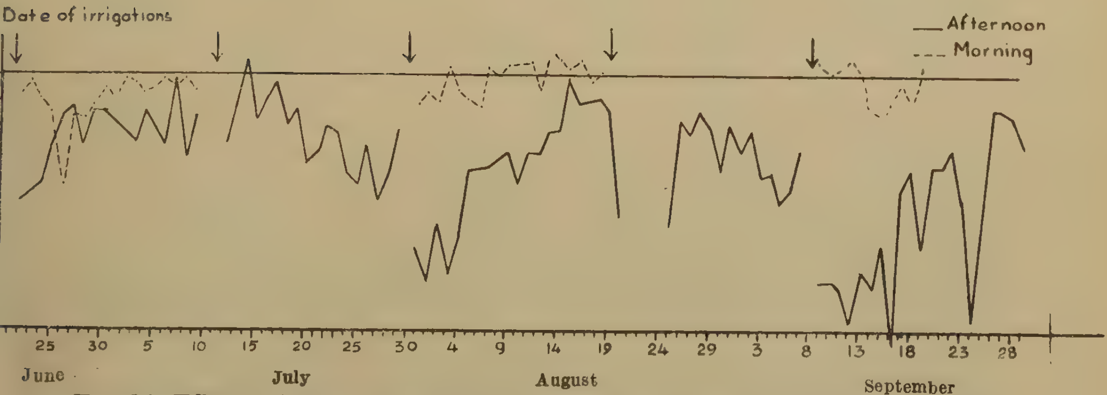


FIG. 14. Effect of irrigation and crop on temperatures during the *kharif* season 1935 (Deviations of temperatures observed inside the crop from those in the open at 6 in. height).

In the afternoon, irrigation and cropping make very wide differences in the temperature conditions of the local environments. During the second and third phase of plant growth the differences between the two go to about 7° to 9° C. while in the first stage they are about 3° to 4°C. only. This brings out the effect of the growth of the crop and consequent shading very markedly. The effect of irrigation alone is seen in Fig. 4, when the crop was about six inches high only. The greater quantity of water vapour over an irrigated bed has lowered the temperature, but this effect lasts only up to five to eight days after irrigation. The effect of crop has been to add shade to the effect of water vapour in modifying the local climate inside the crop. In the open, the highest temperatures are observed at six-inch height, while the cropped beds at six-inch height show the lowest temperatures at this time. Ramdas and others [1934] found comparatively a lower correlation between the two conditions at this hour. Our figures would give still lower values.

Soil temperatures

It may be marked that the morning and afternoon temperatures in the soil do not represent the minimum and maximum epochs as in case of air temperature. The minimum temperatures in the soil is reached by 08-00 to 10-00 hours I.S.T., and the maximum by 19-00 to 21-00 hours at night. The records at sunrise and afternoon (16-00 hours) are only two points on the decreasing and increasing curves. Under cropped conditions in all phases of growth the temperatures continue falling till about two to three days after irrigation. This is probably due to the evaporation of free water in the soil which withdraws heat from its mass and reduces the temperature. Later on, there are two opposite tendencies working one against the other, which give the resultant values. While the moisture in the soil is evaporating and is responsible for the cool temperatures as a whole, the heating effect of solar radiation tends to bring up the temperatures as the soil gets drier.

Relative humidity

Relative humidity shows mostly inverse relationship as compared to temperature. In the morning, the difference between cropped and uncropped situation is not very great because the values reach very near the maximum point. There is thus a high correlation between the figures obtained in the two situations at this time. During the latter two periods, *e.g.*, August and September, when the general minimum temperatures are lower, the correspondence between the relative humidity outside and inside the crop is greater. The widest differences are seen at the six-inch height above ground.

In the afternoon, when relative humidity is low, the differences between cropped and uncropped beds are very great. During the first phase of growth when the plants are only about 1/2 to 1 ft. high, the differences are not very pronounced, because the plants have not as yet created a separate environment. During the latter two stages, the relative humidity in the afternoon is considerably higher inside the crop. It is highest for a few days after irrigation and then begins to fall down and level up with the outside conditions. The causes of wide fluctuations on certain days, as in the case of temperature, are probably due to changes in wind and radiation at the time of observation. The effect of crop and irrigation diminishes as the height above the ground level is increased.

General

Comparing the micro-climatic condition both inside and outside a crop with the data obtained from screen values it is observed that the outside conditions exert the basic pull on all situations. The standing crop by cutting out solar radiation and by transpiration modifies the internal atmosphere considerably. There is, as it were, a perpetual cloudy weather inside the crop. This effect is most pronounced during the day in summer. Under irrigation, the intervals of waterings have probably the largest modifying effect. The temperature and humidity conditions differ to the greatest extent just after irrigation, and then slowly try to run parallel in both the environments. This gives the characteristic periodical fluctuations in the environment inside the crop which may have very great effect on the daily growth rate of plants.

The growing plant thus experiences a variety of climatic conditions during its life. Apart from the daily weather changes the frequency and the quantity of irrigation has a dominating influence on the climate inside and over a crop specially in arid tracts. The shade of the crop creates a different condition for those organs which lie inside and from where direct sunlight is cut off. The top and sides of the plants, which get direct sun for different periods during the day, experience an altogether separate environmental complex. Looking to the susceptibility of the plant tissues to changes according to external conditions, it is no wonder that the population of a field crop shows such wide variations in the matter of its growth and scaffolding.

V. SUMMARY

Data on temperatures and relative humidity conditions recorded by means of an Assmann Psychrometer both inside and outside a cotton crop during the *kharif* season of 1935 at three typical heights above ground are presented and discussed.

During the earliest phase of growth, when the crop is young, irrigation reduces temperatures and increases humidity over cropped bed to some extent. During the latter states of growth the differences between the two environments are great, specially during the hour of the day.

Temperatures are highest at six-inch height above ground on a barren plot which decrease as the height is increased up to three feet to four feet. This tendency is reversed under cropped condition specially when plants have covered up the soil wholly and have attained a height of three to four feet.

Soil temperatures show wider differences. The uncropped open beds show about 8°-10°C. higher temperatures than the cropped ones for a few days after irrigation. The tendency of the temperatures to run closer as the soil gets drier is seen in all phases of growth. The lowest soil temperatures are reached just after a few days of irrigation.

The figures of temperatures and relative humidity from instruments exposed at four feet height in the Stevenson Screen nearby do not show real conditions inside a crop. The most dominating feature of the microclimate of the cotton field under irrigation is the periodic fluctuation due to the intervals of irrigation. This rhythm is superimposed over the daily drift observed in ordinary air temperatures. The influence of crop growth lies in creating shade conditions inside.

ACKNOWLEDGMENTS

The work was carried out at the Agricultural Research Station, Sakrand under the Sind Physiological Research Scheme financed by the Indian Central Cotton Committee, Bombay.

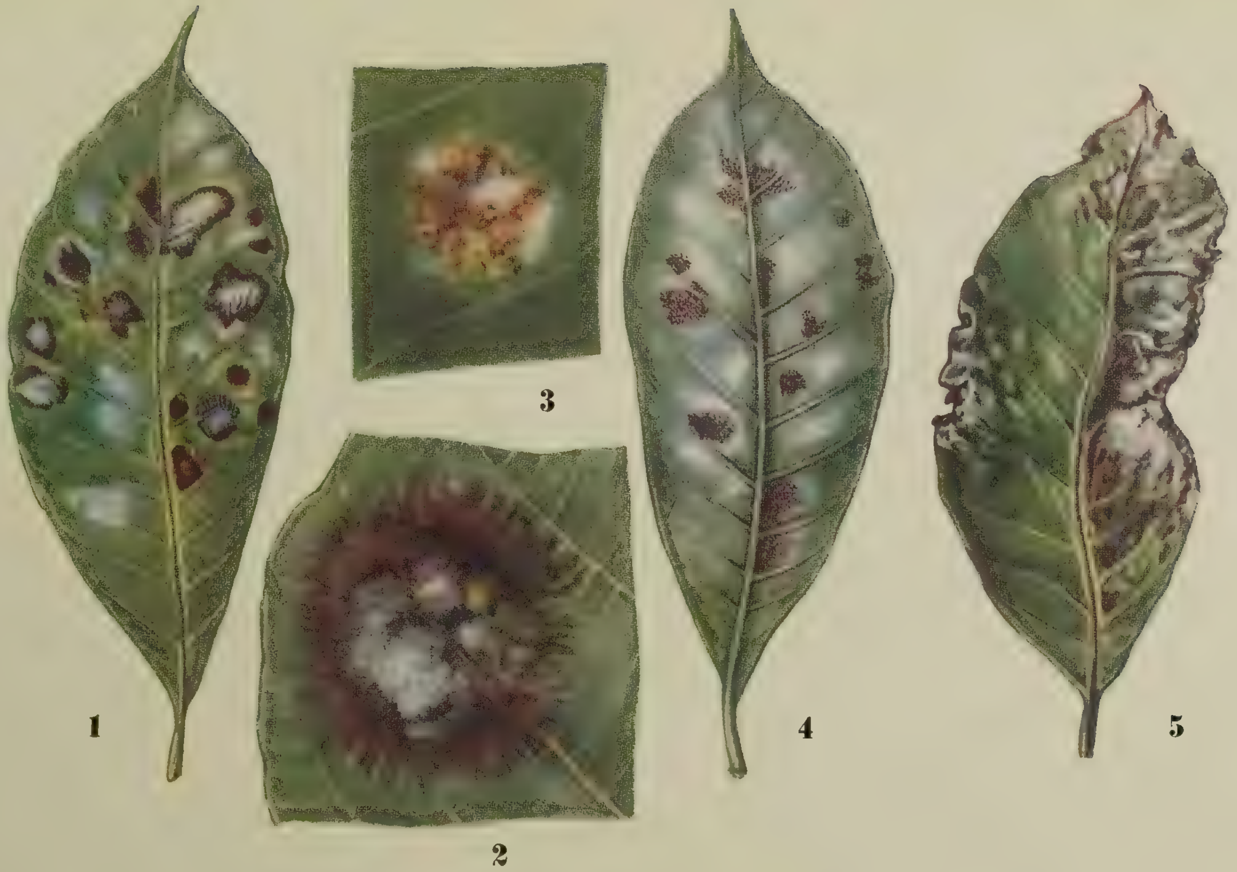
Our thanks are due to Mr. R. C. Sharma, Chief Meteorological Observer on this scheme, for assistance in the collection of data.

REFERENCES

Ramdas, L. A.; Kalamkar, R. J. and Gadre, K. M. (1934). *Ind. J. Agric. Sci.* **4**, 451-67.

———————————— (1935). *Ind. J. Agric. Sci.* **5**, 1-11.

PLATE VIII



1. Ventral surface of mature leaf showing the diseased spots and chlorosis. (Natural size)
2. Magnified view of a spot of mature leaf.
3. Nature of the spot on which fructification of *O. hevae* was noted. (Natural size)
4. Dorsal surface of a mature leaf showing spots. (Natural size)
5. A leaf with distorted margin due to the coalescence of spots. (Natural size)

SOME LEAF DISEASES OF *HEVEA BRASILIENSIS* NEW TO INDIA

BY

M. MITRA AND P. R. MEHTA

Imperial Agricultural Research Institute, New Delhi

(Received for publication on 25th October 1937)

(With Plate VIII)

INTRODUCTION

EARLY in 1936 a disease of the young leaves of rubber plant (*Hevea brasiliensis*) was noticed to do a good deal of damage at the time of annual refoliation (in February and early March) and was accompanied by shedding of new leaves. The Superintendent of Vailamully Estate, South Travancore, very kindly supplied the specimens and the required information.

SYMPTOMS

The disease was noticed on young and semi-mature leaves simultaneously but the symptoms varied with their age. The young leaves were shrivelled or curled along the edges and had no definite spots, and those slightly infected remained on the tree in a distorted condition whereas the badly attacked soon dropped.

The mature leaves were badly spotted on both sides and did not drop from the trees. The young spots were usually round with a 'deep grayish olive'* stellate central part surrounded by a narrow 'tawny'* coloured margin (Plate VIII, figs. 1 and 4). In its centre a closely adpressed superficial fungus growth, more commonly seen on the upper surface of the leaf, composed of fine radiating threads could be seen with a lens. On the under surface the spot had an 'olive brown' centre and a broad 'orange cinnamon' margin. Chlorosis of the leaf tissue between and around the spots was very conspicuous. The mature spots had crinkled margin and were very irregular, mostly angular, usually isolated, 0·4 to 1·0 cm. across, deep grayish olive with velvety appearance, and the grayish white fungus growth occupied about two-thirds of its area (Plate VIII, fig. 2). Coalescence of the spots which was common near the margin of the leaf badly distorted a considerable area (Plate VIII, fig. 5). Such leaves comprised a large percentage of the diseased leaves. The colour of the spots became faint in older leaves but the crinkle persisted.

---

* Ridgway, R. "Colour Standards and Nomenclature," 1912.

Sometimes young leaves showing symptoms very much as in mature leaves, but with lighter brown spots, and a more powdery superficial mycelium, were also noted (Plate VIII, fig. 3).

MICROSCOPIC CHARACTER

Microscopic examination of the very young, shrivelled leaves showed traces of superficial fungus growth composed of hyaline, septate mycelium, 1-2μ thick without reproductive bodies, but sections of the leaves showed the presence of haustoria in epidermal cells, suggesting the presence of a fungus of the *Erysiphaceæ* group. In many sections hyphae in the deeper tissues were also noticed. On incubation of the leaves in moist chambers, numerous acervuli of a species of *Gloeosporium* readily appeared on the surface. Tissue cultures of the leaves also developed constantly into a similar species of *Gloeosporium* in the culture media. The acervuli were scattered or confluent, about 200μ in diameter, dark at first but pink when ripe; conidia were straight, oblong with rounded ends, 13·2-22·2×3·5-4·2μ. The species resembles *Gloeosporium alborubrum* Petch [Petch, 1921].

Examination of the sections through the infected spots on mature leaves showed that the browning was due to the accumulation of pigment in the subepidermal layers. Hyphae were rarely found in the tissues but haustoria were commonly seen in the epidermal cells. When the leaves were incubated under sterile conditions, numerous acervuli of *G. alborubrum* developed on the chlorotic area and near the margin of the spots but never on them. On some leaves setose acervuli also developed and later perithecia of a species of *Glomerella* also appeared. The ascospore cultures also gave rise to the *Colletotrichum* species. The setose acervuli on the leaves were black at first, pink later; 80-124×60-80μ in size; setae two to three septate, 60-114μ long (usually 90μ); conidia oblong with one end usually more acute, 13·2-17·6×4·2-5·5μ; basidia club-shaped, 22-24×6·5μ. The perithecia on the leaves were dark, sub-spherical, beaked, 240-320μ in diameter; asci sessile, or sub-sessile, 52-60μ long, eight spored; ascospores hyaline, allantoid, one-celled, 13·2-16·2×4·2μ in size; paraphyses absent. This *Colletotrichum* has been determined to be *Colletotrichum ficus* Kds. known on *Hevea*, which is said to be identical with *Gloeosporium elastica* Cke. and Mass. and *Glomerella cingulata* (Stonem.) S. and V. S. [Weir, 1926].

From the symptoms it was suspected that the spots were due to *Oidium hevae* Steinman recorded from several countries, but the constant appearance of a *Gloeosporium* and *Colletotrichum*, and the absence of conidiophores and oidia, together with the lack of any authentic specimens of the *O. hevae*, left the determination incomplete. Specimens of *Oidium hevae* were therefore obtained from the Mycologist, Department of Agriculture, Peradeniya, Ceylon, for comparison, to whom our thanks are due. These specimens had symptoms which resembled those of Indian specimens except that most of the spots were lighter in colour and the 'oidium' stage was manifest. A few darker spots with crinkled margin, having velvety growth without any fructification on them were also present. This led to the belief that the spots in the Indian specimens were mostly due to *O. hevae*. This was confirmed when a further lot of fresh specimens of Indian material was obtained. They showed the presence of conidiophores and oidia. The latter were barrel-shaped, 26-34× 14-16µ.

DISCUSSION AND CONCLUSION

It is known that the symptoms of the disease caused by *O. hevae* differ with age of the leaf and the time of the attack of the disease. Park [1927] distinguishes two kinds of symptoms; one due to 'primary attack' occurring on young leaves at the time of their early growth and rapid expansion: it may lead to discoloration and curling of the leaves from the margin and to defoliation, or on slightly older leaves in which there is no defoliation, areas near the tip and mid-rib are discoloured and distorted "due to the healthy portions continuing to expand while the diseased area not being able to do so". The other due to 'secondary attack' occurring on full-grown leaves was different from the above: here irregular, yellowish translucent spots appeared which later turned purple brown.

In Indian specimens mature leaves had numerous purple brown spots and crinkling was always present around their margin, as would be expected if the growth of the tissue occupied by the spot had ceased to grow while the surrounding tissue had continued to grow. It, therefore, seems likely that the leaves were attacked in the semi-mature stage, which is also in evidence by a large number of leaves having distorted edges. Leaves with yellow and translucent spots, recalling the symptoms of secondary attack on mature leaves as described by Park [1927], were also noticed but even these had a crinkled margin indicating that these patches were also attacked in their age of rapid expansion. It seems likely that this stage, full of conidiophores and oidia, eventually matures to purple brown spots in old specimens which were devoid of any fructification but showed the presence of haustoria. Bobilioff [1928] has also noted in Java that older spots were often devoid of fructifications and suggests that "it is very probable that fungus winters in this form and infects next year the leaves. This infection must be attended with the formation of conidia".

The symptoms noted in the Indian specimens very nearly resembled those shown in the coloured illustrations (Figs. 3, 5, 6 and 7) of Bobilioff [1928].

Sharples [1926] noted certain diseased symptoms on *Hevea brasiliensis* in Malaya similar to those noted by Gadd [1926] in plants attacked by *O. hevae* in Ceylon, *e.g.*, distortion of leaves along the edges and leaf shedding, but the organism responsible was found to be *Gloeosporium alborubrum*. As has been stated before, the Indian specimens showed both *O. hevae* and *G. alborubrum*, and it is probably a case of mixed infection leading to defoliation and curling in very young leaves. In slightly older leaves, that had not been shed, *O. hevae* and *G. alborubrum* were also noted. As for the presence of *Colletotrichum ficus* it is likely that these were secondary infections. Sporulating acervuli of this species of *Colletotrichum* were very common on the petioles.

Dry weather is said to favour the mildew on rubber leaves in other countries and in India the disease was first recorded under similar weather conditions.

SUMMARY

A disease of young leaves of rubber plant (*Hevea brasiliensis*) was reported early in 1936, at the time of annual refoliation, from a plantation in South Travancore. The young and semi-mature leaves were attacked simultaneously but the symptoms varied with the age of the leaf. The young leaves were free from any spots, shrivelled along the edges and were readily shed from the trees. The semi-mature and mature leaves were spotted on both sides but did not drop from the trees. The brown-gray spots had a crinkled margin and looked velvety due to a closely adpressed grayish white fungus growth on their surface.

Microscopic examination of young leaves showed haustoria in the epidermal cells but sometimes hyphae in the deeper tissues were also noted. The diseased leaves developed acervuli of *Gloeosporium alborubrum* in moist chambers and in culture media. Most of the spots on older leaves had no fructification but on some 'oidium' stage of *Oidium hevae* Steinman was manifest. Other fungi isolated from mature leaves were *G. alborubrum, Colletotrichum ficus* Kds. and its perfect stage, *Glomerella cingulata* (Stonem.) S. and V. S.

Gloeosporium alborubrum and *Oidium hevae* are known to be responsible for abnormal leaf fall in other countries. The presence of both these fungi in the Indian material, therefore, seems to be the likely cause of abnormal leaf fall. These fungi are for the first time recorded in India.

REFERENCES

Bobilioff, W. (1928). *Arch. voor Rubbercult. Nederl-Indie* **12**, 199-206.

Gadd, C. H. (1926). *Dept. Agric. Ceylon Year Book*, 22-23.

Park, M. (1927). *Trop. Agric.* **69**, 147-150.

Petch, T. (1921). 'The Diseases and Pests of Rubber Tree'. Macmillan and Co., London.

Sharples, A. (1926). *Malayan Agric. J.* **14**, 88-90.

Weir, J. R. (1926). *U. S. Dept. Agric. Dept. Bull.* **1380**.

NOTE ON *CEPHALOSPORIUM SACCHARI* BUTL.

(CAUSAL ORGANISM OF SUGARCANE WILT)

BY

L. S. SUBRAMANIAM

AND

B. L. CHONA

Imperial Agricultural Research Institute, New Delhi

(Received for publication on 15th November 1937)

CEPHALOSPORIUM SACCHARI BUTL. was described by Butler and Hafiz [1913] as the cause of a wilt disease of sugarcane in India. Further study of this fungus has always shown some differences from the original description. It has also been noticed that the fungus commonly attacks the top portions of the stem of sugarcane rather than starting from the base. In many cases the plants do not wilt.

Cephalosporium sacchari isolated at Pusa in 1921 and sent to Europe was reported to have produced *Fusarium* spores. Cultures sent to the Centraalbureau voor Schimmelcultures, Baarn, Holland, in 1935 also produced *Fusarium* spores, and were identified as belonging to the *Fusarium moniliforme* group.

Early this year isolations of *Cephalosporium sacchari* from Coimbatore and Sepaya and *Fusarium moniliforme* from Karnal were sent to the Imperial Mycological Institute, Kew. The following is the report on these cultures very kindly supplied by Mr. Mason and Dr. Bisby to whom our grateful thanks are due :

1. "Two cultures marked *Ceph. sacchari*—(Coimbatore and Sepaya): Both are the same fungus. The mycelium is white or whitish on clear maize meal agar and potato dextrose agar and pink on rice. The reverse of potato dextrose agar becomes bluish-green. The spores are elliptic, somewhat narrowed at the ends, hyaline, mostly 7-13 × 1·5-2·5μ and non-septate, occasionally 1-septate and 10-18 × 2-3μ, very rarely 2-septate ; never broadest towards the apex, as is characteristic of the micro-conidia of *Fus. moniliforme*. No spores resembling the macroconidia of *Fusarium* were seen. The spores are borne in small slimy heads, never in chains. The rather indefinite conidiophore may continue to elongate, leaving a small heap of spores behind. Chlamydospores appear to be absent."

" It will be seen that this fungus has a number of the features of *Ceph. sacchari* as described by Butler. There are certain apparent points of divergence, as follows : (*a*) it is stated for *C. sacchari* that ' the mycelium remains white '. This is not true of the present fungus. (*b*) the spores appear to stick together more than recorded for *C. sacchari*. (*c*) the spores of *C. sacchari* are stated to be ' almost invariably unicellular when formed, but some become septate prior to germination '. The spores of the present fungus are perhaps more commonly septate at first than in *C. sacchari*."

" The fungus is not a typical *Cephalosporium*, but it is the same type of fungus as *C. sacchari*, and comes nearest to that species of any we have seen described."

2. " A culture marked *Fusarium moniliforme* from Karnal : This is correctly determined. The microconidia are in chains, which sometimes collapse to form heads, and are the right shape. A few macroconidia were seen ".

Mr. Ashby also reports that the culture sent to Dr. Westerdijk, Centraalbureau voor Schimmelcultures, Baarn, Holland, marked as *Cephalosporium sacchari*, has given conidia of *Fusarium* in subculture and that it appears to be *Fusarium moniliforme* var. *subglutinans* (*Gibberella fujikuroi* (Saw.) Wr. var. *subglutinans* Edw.).

Inoculations with this fungus on canes have produced symptoms as described by Butler and Hafiz except that the canes did not wilt. The above facts strongly suggest that *Cephalosporium sacchari*, as described by Butler, belongs to the *Fusarium moniliforme* group.

Fusarium moniliforme is very common on sugarcane in India associated with ' Pokkah boeng ' or ' Top-rot ' disease. Numerous inoculations with this fungus on different cane varieties have failed to produce any symptoms characteristic of the wilt disease.

Further work to determine the exact systematic position of *Cephalosporium sacchari* with reference to Top-rot and Wilt is in progress.

REFERENCE

Butler, E. J. and Abdul Hafiz Khan (1913). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **6**, 181-190.

STUDIES ON *PLATYEDRA GOSSYPIELLA* SAUNDERS (THE PINK BOLLWORM OF COTTON) IN THE PUNJAB

119

PART IV. THE INCIDENCE OF *PLATYEDRA GOSSYPIELLA* IN RELATION TO CLIMATE (1926-1931)

BY

M. HAROON KHAN, B.Sc. (Lond.), A. R. C. S.

Assistant Cotton Entomologist, Entomological Laboratory, Punjab Agricultural College, Lyallpur

(Received for publication on 23rd December 1937)

(With three text-figures)

CONTENTS.

		PAGES
I.	INTRODUCTION	191
II.	SEASONAL HISTORY OF THE COTTON CROP AND OF *P. gossypiella* IN THE PUNJAB	192
III.	METHOD OF INVESTIGATION	194
IV.	DISCUSSION OF THE DATA	194
V.	DISTRIBUTION OF *P. gossypiella* IN RELATION TO CLIMATIC CONDITIONS	199
VI.	SUMMARY	213
	REFERENCES	214

I. INTRODUCTION

BINDRA [1928] studied the distribution of *P. gossypiella* in the Punjab during 1923-1925, and arrived at the conclusion that, with the highest intensity of attack in the south-eastern part of the province, this pest continued with decreasing severity in the sub-montane tract and towards the central districts, and reached its lowest limits in the Canal Colonies and the dry area further west. Since 1926 the distribution and incidence of this pest has been studied in greater details and the present paper embodies the data collected during the six years, 1926 to 1931. In general Bindra's conclusions find support, but it is in some parts of the sub-montane tract or the central Punjab that the incidence is the highest.

The research work presented in this paper was financed by the Indian Central Cotton Committee. The generosity of the Committee is gratefully

acknowledged. This work was carried out under the guidance of Mr. M. Afzal Husain, Entomologist to Government, Punjab, to whom the author expresses his sincerest thanks for directing this investigation, supervising it during the course of its progress and giving much valuable help in the preparation of the manuscript. The help rendered by the district staff of the Department of Agriculture, Punjab, and the useful advice given throughout by Mr. Mohammad Afzal, Cotton Research Botanist, Lyallpur, is also acknowledged thankfully.

II. SEASONAL HISTORY OF THE COTTON CROP AND OF *P. GOSSYPIELLA* IN THE PUNJAB

For a vast tract, stretching from the foot of the Himalayas to the arid desert tracts of Rajputana, Sind and Baluchistan, covering about 94021 square miles, and presenting varied conditions of soil and cultivation, and extreme variations in climate, it is very difficult to give an account of the seasonal history of either the cotton crop or Pink Bollworm, which would be of general application. Further, annual fluctuations in climate, which influence both the cotton plant and this pest, make such a generalisation still more difficult. Subject to these reservations the average conditions are described below :—

1. *Cotton crop* (desi)

Cotton sowings, in the Punjab, commence as early as the end of March and continue as late as June or even July, depending upon the local conditions. According to Trought [1928] and Trought and Afzal [1930], the beginning of May is usually accepted as the best time for sowing the *desi* varieties in the Canal Colonies. Picking starts from about the middle of September, and if conditions are favourable, it may continue till about the end of January. This may be taken to represent the general position in most of the cotton-growing tracts of the Province, but in the south-eastern Punjab, the time of sowing is about a fortnight earlier. Picking starts from about the beginning of September and is over by about the middle of November.

2. *Pink Bollworm*

In the Punjab *P. gossypiella* has two distinct types of life-cycle : (*a*) the 'short cycle', in which the caterpillars on becoming full-fed, pupate immediately, and (*b*) the 'long cycle', in which the full-fed caterpillars enter a resting stage, inside the hollowed out cotton seeds or, rarely, in lint, and remain in this condition for a period of several months. Full-fed caterpillars begin to enter this resting stage by the beginning of October and, generally, by about the end of this month all larvae have entered this stage of quiescence. A few of the 'long-cycle' caterpillars may pupate as early as the end of March and the first moths may appear in April, but the main rush of pupation occurs after the onset of the monsoon rains, *i.e.* in July or occasionally during the latter part of June, and the largest number of moths emerges during July and the first half of August. The fate of the moths emerging from April to the end of June is uncertain. Probably their progeny does not survive. Absence of food may be responsible for this, and, equally likely, adverse climatic conditions, *i.e.*, high temperature and low relative humidity, may account for their death. It is undoubtedly the progeny of the moths emerging during the latter months, *viz.*, July and August, which is mainly responsible for starting the attack on the new cotton crop.

It is evident that the incidence of the pest will, to a certain extent, depend upon the initial population of the moths at the beginning of the season, but mainly upon the degree of the intensity of environmental resistance offered to the biotic-potential of the insect. Pink Bollworm moths may lay as many as 450 eggs, and during July and August its life-cycle, under field conditions in the Punjab, is completed in nineteen days. With such high biotic-potential, its rapid increase under favourable environmental conditions even from small beginnings is assured. The variation in incidence, therefore, is the direct result of environmental resistance.

The attack starts with the appearance of the floral buds and shifts on to the green bolls as soon as they appear, and continues with increasing severity on them till about the middle of November. During this period there are three to four broods of the pest. The progeny of the 'short cycle' moths which emerge up to about the end of October is able to infest the bolls present till about the middle of November, but an increase in the numbers of this insect beyond this date is doubtful.*

To estimate accurately the incidence of this pest during a particular season, one must take into consideration only that period during which the pest is active and green bolls are present. At Rohtak and Hansi very few well-developed green bolls are present before the middle of August, and almost all the bolls have opened by the 1st week of November. The true incidence of attack at these two stations would, therefore, be determined by the examination of bolls from about the 16th of August to the 1st of November. Any observation made after that date would show a very high proportion of attacked bolls, the sound bolls having been all picked. At other stations very few well-developed bolls are present before the beginning of September and there is hardly any increase in the number of the pest after about the middle of November. The boll examination carried out from the 1st of September to 16th November will thus indicate the real incidence of the pest at these stations. This fact has been borne in mind when discussing these results.

---

*It has been found that on account of the sudden fall in temperature, from about the beginning of November, especially the minimum temperature, the number of eggs laid by these moths falls considerably. Besides the incubation period is ten to nineteen days. Therefore, an increase in the number of bolls attacked, while it may continue for sometime after the middle of November, cannot be significant. The results of these investigations will be presented elsewhere.

III. METHOD OF INVESTIGATION

Gough [1917, 1919], the staff of the Entomological Section [1923] and Williams [1926] in Egypt, Loftin, Mckinney and Hanson [1921], and Rude and Smith [1932] in Mexico, Ballard [1921] in South India (Madras Presidency), Bindra [1928] in the Punjab, and Johnston [1929] and Kirkpatrick [1930] in Sudan have studied the incidence of Pink Bollworm by the examination of green bolls, and the same method has been adopted by us. Twelve localities, namely, Rohtak and Hansi (Hissar district) from the south-eastern Punjab, Ferozepore, Ludhiana and Gujranwala from the Central Punjab, Sialkot from the sub-montane tract, Rawalpindi from northern Punjab, Lyallpur, Sargodha and Montgomery from the Canal Colonies, and Multan and Dera Ghazi Khan from the Western Punjab were selected as representing the various regions. Green bolls were examined every year during 1926-1931 from all these localities, with the exception of Rawalpindi and Dera Ghazi Khan in 1929. The plots selected at different stations during different years were usually situated at the Government Agricultural Farms.

The following instructions were issued to the collectors :—

1. that green bolls of the indigenous cottons* (*Gossypium indicum*, *G. neglectum* or *G. sanguineum*) only were to be collected,
2. that collections of 250 green bolls, from the same or a neighbouring field, were to be made on 1st, 8th, 16th and 24th of every month during the period that the bolls were available,
3. that the collections were to be made at random from as many plants as possible ; and
4. that well-developed bolls, not less than half an inch in size, were to be collected.

These instructions were carried out fairly faithfully, except that the collections were occasionally made a day or two earlier or later than the specified dates.

At Rohtak, Sialkot and Lyallpur a number of cotton fields, situated well apart, were under observation and 250 green bolls were examined from each of them on every turn. At each of the other localities collections were made from a single field only.

IV. DISCUSSION OF THE DATA

Table I gives the percentage of green bolls attacked by Pink Bollworm during the most active season at various stations. It will be observed that as the season advances there is a general increase in the incidence of attack. At Sialkot, for example in 1927, the percentage of the green bolls attacked rose from 4·4 to 39, at Hansi, in 1928, the percentage rose from zero to 16·8, at Ferozepore, in 1929, it rose from 4 to 34 and at Rawalpindi, in 1930, it rose from 9·7 to 38·4.

---

*No single variety of indigenous cotton is grown all over the province. Collection of green bolls, therefore, had to be made from different indigenous varieties.

TABLE I

Percentage of green bolls attacked by P. gossypiella *in the Punjab*

(Dates of examination)

Locality	Year	August		September				October				November		
		16th	24th	1st	8th	16th	24th	1st	8th	16th	24th	1st	8th	16th
Rohtak .	1926	...	...	...	0	9·3	9·0	8·0	6·6	8·4	16·6	24·8	...	...
	1927	8·6	10·1	7·0	8·7	9·0	18·6	22·7	29·1	33·7	44·8	47·8	...	...
	1928	0	0·2	3·4	3·9	4·4	12·2	17·2	29·9	19·6	46·6	47·4	...	...
	1929	2·1	3·7	4·7	8·7	10·4	34·9	26·3	34·1	55·9	58·1	71·2	...	...
	1930	13·8	18·5	22·7	25·5	25·3	31·7	36·5	47·9	54·5	60·1	60·2	...	...
	1931	0	0·3	0·8	1·8	2·1	7·0	12·8	27·3	42·4	49·0	76·4	...	...
Hansi .	1926	...	0	0·4	1·2	7·6	9·2	5·6	4·0	8·2	11·6	...	...	...
	1927	3·7	4·0	7·6	10·6	10·0	8·8	10·0	14·4	28·8	40·8	46·8	...	...
	1928	0	1·2	2·4	1·2	3·2	1·2	2·8	9·2	10·4	15·2	16·8	...	...
	1929	3·4	4·4	6·8	8·8	16·0	10·8	11·2	18·4	60·4	50·8	...	...	...
	1930	2·9	3·6	2·0	...	2·4	2·8	7·6	13·2	18·0	48·0	59·2	...	...
	1931	0·9	4·4	1·2	1·6	1·6	3·2	4·4	8·4	21·4	28·8	36·0	...	...
Ferozepur .	1926	...	...	1·6	16·4	7·5	8·0	15·6	7·8	14·0	30·8	12·4	23·6	20·3
	1927	...	...	8·6	37·2	37·5	14·8	20·8	35·2	43·1	52·0	33·6	43·6	58·0
	1928	...	...	...	...	4·8	4·4	5·6	3·6	3·6	5·2	5·4	5·2	1·6
	1929	...	...	4·0	1·2	7·6	8·8	9·6	8·4	18·4	20·4	17·2	27·2	34·0
	1930	...	...	18·4	13·2	20·0	16·4	22·4	26·0	28·0	34·8	40·8	46·6	36·8
	1931	...	...	0	1·2	2·8	4·4	10·4	10·0	19·6	21·2	27·6	65·0	46·8
Ludhiana .	1926	...	...	15·2	22·0	17·0	20·0	20·0	44·8	34·0	44·4	28·8	34·4	...
	1927	...	...	26·4	6·4	21·6	14·7	24·0	13·6	18·0	14·6	22·8	15·2	12·0
	1928	...	...	2·4	3·2	2·8	7·2	8·0	10·4	10·2	4·8	5·2	1·6	6·1
	1929	...	...	6·5	13·6	27·4	18·0	9·2	16·4	19·2	26·8	42·4	38·0	26·8
	1930	...	...	...	...	17·2	15·2	12·0	21·2	42·0	29·6	51·6	58·8	50·8
	1931	...	...	16·0	20·0	30·7	25·4	24·8	32·4	37·2	48·8	41·6	49·6	46·4
Gujranwala	1926	...	...	0	0·4	0·8	0	2·8	3·6	6·8	6·8	14·4	...	14·8
	1927	...	...	12·0	10·8	14·9	12·4	20·8	17·6	25·6	22·8	31·6	29·4	44·4
	1928	...	...	0·4	0·4	0·8	3·5	2·8	6·8	2·3	3·6	...	4·4	5·7
	1929	...	...	0	0·8	2·4	7·2	4·0	...	10·0	54·4	44·4	27·6	31·2
	1930	...	...	3·0	0·5	2·5	5·6	17·3	28·8	23·0	27·2	30·4	26·8	34·0
	1931	...	...	1·8	5·6	4·8	9·3	28·3	21·3	14·8	20·2	16·8	12·0	15·6
Sialkot .	1926	...	...	3·1	0·9	1·4	0·9	4·0	6·6	11·7	12·0	12·6	24·3	18·9
	1927	...	...	4·4	9·6	12·7	16·6	21·9	19·3	19·4	23·1	24·9	32·1	39·0
	1928	...	...	8·6	9·7	11·9	26·2	30·2	25·8	21·6	17·2	13·1	15·0	13·3
	1929	...	...	2·1	6·1	7·9	9·9	10·9	13·1	21·8	29·8	34·6	40·3	33·9
	1930	...	...	12·0	15·6	21·2	24·4	34·4	50·8	46·0	39·6	40·8	36·0	39·6
	1931	...	...	17·6	16·2	14·0	13·8	34·3	36·2	37·4	40·5	32·8	30·8	28·8

TABLE I—*contd.*

Locality	Year	August		September				October				November		
		16th	24th	1st	8th	16th	24th	1st	8th	16th	24th	1st	8th	16th
Rawalpindi	1926	...	...	...	10·0	7·6	10·0	14·4	18·4	34·4	22·4	26·7	17·2	25·7
	1927	...	...	8·2	15·8	12·0	10·6	13·7	16·5	18·5	24·6	32·2	33·0	27·0
	1928	...	...	4·6	6·8	5·8	13·2	11·0	21·5	19·6	29·2	17·6	13·1	6·2
	1929	...	...	...	...	...	...	...	...	...	...	...	...	...
	1930	...	...	9·7	10·4	8·8	15·2	14·4	16·6	24·8	24·8	35·6	32·8	38·4
	1931	...	...	1·6	4·4	11·1	...	12·0	13·6	16·0	12·0	15·2	12·8	10·4
Lyallpur	1926	...	...	0	6·6	1·8	1·2	2·4	0·9	3·0	7·6	8·2	8·0	9·9
	1927	...	...	2·9	1·6	2·9	7·1	8·9	13·1	13·3	16·2	17·7	18·3	22·7
	1928	...	...	0·2	0·2	0·1	0·3	0·1	0·4	0·5	0·2	0·2	0·5	0·7
	1929	...	...	2·0	4·4	6·8	1·5	1·2	10·7	4·1	4·9	5·0	3·7	6·6
	1930	...	...	0	0·4	0·4	0·6	2·6	4·0	4·2	2·6	4·6	3·6	2·9
	1931	...	...	0·8	0·2	1·2	2·2	1·2	1·0	2·8	7·2	3·8	4·6	3·6
Sargodha	1926	...	...	4·0	0·3	0·8	0·3	3·2	3·4	6·4	15·2	10·0	22·0	22·4
	1927	...	...	0·8	0·4	0	0·4	0	0·4	1·2	1·6	2·0	2·8	1·6
	1928	...	...	0	0	0·8	0·4	0	0	0	0	0	0	0·4
	1929	...	...	0	...	...	0	0	0	0	0·4	0·8	1·6	1·2
	1930	...	...	0·4	0·2	1·2	2·8	6·0	3·2	5·2	2·4	2·4	2·0	6·0
	1931	...	...	0·4	0	1·6	1·2	0·8	1·6	...	1·6	0	2·0	1·2
Montgomery	1926	...	...	0	0	0	0	0	3·8	...	1·4	0·5	0	1·0
	1927	...	...	0	0	0	0·4	0·4	1·2	0	2·6	3·4	2·6	1·5
	1928	...	...	0	0	0	0	0	0	0·4	0	...	0	0·4
	1929	...	...	0·2	0	0	0	0	0	0	0	0	1·2	...
	1930	...	...	0	0	0	0	0	0	0	0	1·2	0	0·4
	1931	...	...	0	0	0	0	1·2	0	0·8	1·4	0·4	0	0·8
Multan	1926	...	...	...	0	1·3	0·3	4·4	4·4	5·2	1·9	3·3	2·8	1·1
	1927	...	...	0	0	0	0	0	0	0	0	0	0	0
	1928	...	...	0	0	0	0	0	0	0	0	0	0	0
	1929	...	...	0	0	0	0	0	0	0	0·4	0·4	0·8	0
	1930	...	...	0	0	0·4	0	0·4	0	0·4	0	1·6	0·6	4·8
	1931	...	...	0	0	0·4	0	0	0	0	0	0	0	0
Dera Ghazi Khan	1926	...	...	4·2	2·5	1·2	0	9·2	7·2	10·3	24·4	17·8	13·1	10·8
	1927	...	...	...	0	1·2	0·4	0·8	4·7	4·3	14·5	11·7	16·9	7·5
	1928	...	...	...	1·0	0·4	0·4	0	0	0	0	0	0·4	0
	1929	...	...	...	...	...	...	...	...	...	...	...	...	...
	1930	...	...	0	0·4	0·4	4·0	1·6	0·8	0·3	0·4	1·6	2·8	2·4
	1931	...	...	0·5	0	0	0	0	0	0	0·8	0	0	0·4

Further, it will be observed from this Table that at certain stations, such as Multan and Montgomery, the attack is always negligible and is seldom higher than three per cent of the bolls present. At other stations, for example Lyallpur and Sargodha, the attack is low and, except during certain years, not more than ten per cent of the bolls are ever attacked, while at places, such as Rohtak and Sialkot, the attack is much higher, and over twenty per cent of the bolls are damaged late in the season every year and very often even over forty per cent of these may be attacked.

Again, it will be observed from the data collected that even at the same station the attack of this pest varies from year to year. Thus at Rohtak the percentage of attack rose from zero to 20·8 in 1926, but in 1930 it rose from 13·8 to 60·2. Similarly at Lyallpur the percentage of attack rose from 0·2 to 0·7 in 1928, but in 1927 it rose from 2·9 to 22·7, and at Gujranwala the attack rose from zero to 14·8 in 1926, but in 1931 it rose from 3 to 34.

To make comparisons between the regional and seasonal incidence of Pink Bollworm easier, the percentage of green bolls attacked during different years has been calculated. The average of six years has also been calculated and given in Table II.

As stated above it will be clearly seen from Table II that the attack of Pink Bollworm varies from place to place. At Ludhiana, where the intensity of attack is the highest, the average percentage of green bolls attacked for six years works out at 23·4, at Ferozepore it works out at 19·1, at Hansi at 12·2, at Lyallpur at 4·3 and at Montgomery at only 0·3. Fig. 1 is a diagrammatic representation of the mean intensity of attack at different stations.

Further, it will be observed from Table II and Fig. 1 that at all the stations from the Canal Colonies—Lyallpur, Sargodha and Montgomery, and the western Punjab—Multan and Dera Ghazi Khan, from which green bolls were examined, the attack was very little or even negligible, while elsewhere the attack was mild or serious.

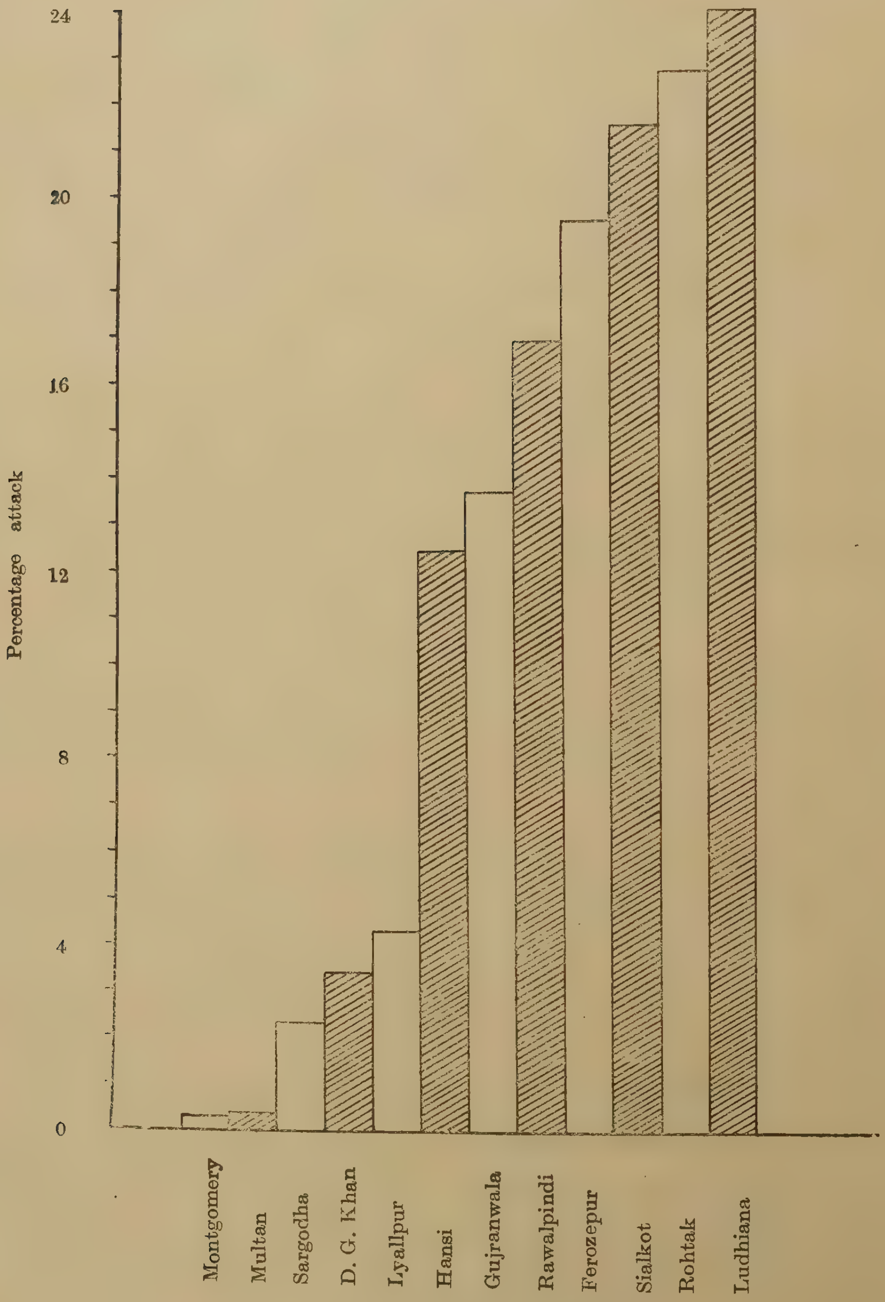


FIG. 1. Mean percentage attack, 1926-31

On the basis of the intensity of Pink Bollworm attack we may broadly divide the Punjab into the following four zones :—

1. The zone of 'normal outbreaks', where this pest is serious and the percentage of green bolls attacked is on an average above fifteen.
2. The zone of 'occasional outbreaks', where the attack is mild and the percentage of green bolls attacked is on an average above five and up to fifteen.
3. The zone of 'possible outbreaks,' where the attack is very little and is on an average above one and up to five per cent.
4. The zone of 'no outbreaks', where the attack is negligible and is on an average one per cent or less.

Having shown differences in the intensity of Pink Bollworm attack in different parts of the province, we turn to the main question. Why is this pest so unevenly distributed in the province? If we can give a satisfactory answer to this question it would be easy to explain differences in attack at the same stations during different years.

TABLE II

Percentage of green bolls attacked at different stations throughout the season, 1926-31

Stations	1926	1927	1928	1929	1930	1931	Average of six years
Rohtak	10·3	21·8	16·8	28·2	36·1	20·0	22·2
Hansi	5·3	17·0	5·8	19·0	16·0	10·2	12·2
Ferozepur	14·4	35·0	4·4	14·2	27·6	19·0	19·1
Ludhiana	28·1	17·2	5·6	22·2	33·2	33·9	23·4
Gujranwala	5·0.	22·0	3·1	18·2	18·1	13·7	13·4
Sialkot	8·8	20·3	17·5	19·1	33·6	27·5	21·1
Rawalpindi	18·7	19·4	13·6	..	20·5	10·9	16·6
Lyallpur	4·5	11·3	0·3	4·6	2·4	2·6	4·3
Sargodha	8·0	1·0	0·1	0·5	2·9	1·0	2·3
Montgomery	0·8	1·1	0·1	0·1	0·1	0·4	0·3
Multan	2·5	0	0	0·1	0·7	0	0·4
Dera Ghazi Khan . . .	9·1	6·2	0·2	..	1·3	0·2	3·4

V. DISTRIBUTION OF PINK BOLLWORM IN RELATION TO CLIMATIC CONDITIONS

The influence of climate on the activities of insects, particularly their distribution, population and economic status, has been very fully discussed by Uvarov [1931]. The relationship between climate and incidence has been established in the case of such important pests as the Cotton-boll Weevil in

America [Hunter and Pierce, 1912], the Cotton-seed Bug in Egypt [Kirkpatrick, 1923], the Plague flea in India [Rogers, 1928] and the Hessian Fly in the United States of America [Packard, 1929]. The influence of climate on Pink Bollworm has not so far been studied with any degree of precision.

It has been stated [Bindra, 1928 and Afzal Husain, 1930], that in the Punjab climatic variations, from place to place, are responsible for the uneven distribution of this pest. Recently it has been shown [Afzal Husain, Haroon Khan and Nazir Ahmad, 1935], that in those parts of the Punjab where the incidence of attack is high, the climatic conditions are favourable for the procreation of Pink Bollworm moths and they lay a larger number of eggs, while in parts of the province where the incidence of attack is low, the climatic conditions are unfavourable for the procreation of the pest and the moths lay only a small number of eggs. In other words, there is a close correlation between the climate and fecundity of this insect and hence incidence of attack.

Further, it has been shown that the influence of temperature on the pupæ and adults largely determines the capacity for procreation of Pink Bollworm moths. A series of observations have been made by exposing the 'long-cycle' pupæ and the adults emerging from these to different constant temperatures and studying their oviposition (Table III). The results obtained have been summarized below. They throw considerable light on the environmental resistance offered by temperature.

1. The pupæ of the overwintering caterpillars were exposed during July-August to room temperature (mean 90°F.). The moths that emerged were allowed to pair. All the pairs were exposed to four different constant temperatures ranging from 75°F. to 95°F. Out of thirty-one pairs exposed at 95°F., only three females laid eggs and the average was 4·4 eggs per female. At the other three temperatures fifty per cent or more of the females laid eggs, but the average number of eggs laid per female varied from about nine to twelve. This shows that the adults emerging from the pupæ exposed to 90°F. had very reduced oviposition potential.
2. In the case of pupæ exposed to 86°F. constant temperature, the adults on emerging were exposed to 95°F. and out of the seven pairs exposed, four females laid eggs and the average of egg-laying was 12·7. At 86°F. out of twenty-one pairs, sixteen laid eggs and the maximum performance was 200 eggs by a female, and the average 48·7 eggs. At 75°F. out of the nineteen pairs exposed, fourteen females laid eggs and the maximum number of eggs laid was 262 and the average per female seventy-seven eggs.
3. In the case of pupæ exposed to 82°F. during June and July 1933, the adults were exposed to six different temperatures ranging from 59°F. to 95°F. It will be observed from Table III that a very large number of eggs was laid when the pairs

were exposed to 86°F., 82°F. and 75°F. The maximum number of eggs laid was 249 by a female exposed to 86°F., but the highest average of eighty-three per female was at 82°F. and the next best 70·4 at 75°F. Between 68°F. and 86°F. the number of females laying no eggs did not exceed fourteen per cent.

4. When pupæ were exposed during July-August 1933 to 75°F. constant temperature, the best oviposition results were obtained between the temperatures 68°F. to 86°F. It was at 75°F. that a female laid 356 eggs, the maximum record for these experiments, and the average per female was the highest at this temperature, being 97·5, followed by 96·2 at 82°F. It is interesting to note that even when exposed to 95°F. the average egg-laying for these females was 23·4 and almost 36 per cent of them laid eggs.

5. When the pupæ from 'long-cycle' caterpillars were exposed to 68°F. during July and August 1934, and 1935 and the adults emerging exposed to temperatures varying from 68°F. to 95°F., the egg-laying performance was not very high. The highest number of eggs laid by a female was 184 at 68°F. and the highest average per female was 63·4, also at 68°F.

TABLE III

Oviposition of P. Gossypiella *moths under different environmental conditions*

Temperature to which pupæ were exposed (°F.)	Temperature to which moths were exposed (°F.)	No. of pairs under experiment	Highest number of eggs laid by a female	Average number of eggs laid per female	No. of females laying no eggs	Percentage of females laying no eggs
1933— 90	95	31	118	4·4	28	90·3
	86	9	40	11·7	1	11·1
	82	10	52	8·9	4	40·0
	75	54	88	10·5	27	50·0
1933— 86	95	7	51	12·7	3	42·8
	86	21	200	48·7	5	23·8
	75	19	262	77·0	5	26·3
1933— 82	95	22	101	19·0	11	50·0
	86	15	249	56·5	2	13·3
	82	15	200	83·0	2	13·3
	75	10	124	70·4	1	10·0
	68	10	46	28·5	1	10·0
	59	12	19	3·6	7	58·3

TABLE III—*contd.*

Temperature to which pupæ were exposed (°F.)	Temperature to which moths were exposed (°F.)	No. of pairs under experiment	Highest number of eggs laid by a female	Average number of eggs laid per female	No. of females laying no eggs	Percentage of females laying no eggs
1933—	95	14	193	23·4	9	64·3
	86	15	242	71·5	1	6·7
	82	10	162	96·2	0	0
75	75	21	356	97·5	1	4·7
	68	16	172	68·0	1	6·3
	59	12	33	5·4	5	41·7
1934—	95	12	84	24·4	3	25·0
	82	13	94	22·2	4	30·7
68	76	20	172	37·2	6	30·0
	68	13	184	50·4	4	30·7
1935—	94	13	133	35·0	5	38·4
	82	14	164	62·1	2	14·2
68	76	19	105	40·0	4	21·0
	68	9	136	63·4	0	0

It is evident from the above that when pupæ are exposed to temperatures above 82°F. or below 75°F. the moths emerging have reduced oviposition potential, which is greatly reduced if the temperature is above 86°F. Even the moths emerging from pupæ kept at 82°F. or 75°F. when exposed to a temperature above 86°F. lay a small number of eggs, and 95°F. is decidedly unfavourable for the procreative function.

On the basis of the results obtained under controlled conditions, it is possible to establish a relationship between the initial capacity for increase in numbers possessed by this insect and the resistance offered by temperature prevailing in different parts of the province.

The normal mean monthly maximum and minimum temperatures for the different recording stations of the province are given in Table IV. The data presented are practically for the whole of cotton season, May to December, but as the pest becomes active towards the end of June and remains active till October, we will consider the temperature prevailing in different regions during these months only.

TABLE IV

Normal meteorological records of various localities

	May	June	July	August	September	October	November	December
Delhi								
Normal maximum temperature in °F. . . .	104·0	103·3	94·9	92·4	93·0	91·6	82·2	72·9
Normal minimum temperature in °F. . . .	80·2	83·6	81·1	79·8	77·1	68·4	56·7	48·9
Normal rainfall in inches .	0·58	2·99	7·53	7·42	4·78	0·32	0·11	0·4
Normal relative humidity (per cent) . . .	41	55	74	77	71	54	55	63
Ludhiana								
Normal maximum temperature in °F. . . .	103·9	104·7	97·3	94·7	94·3	91·8	80·6	70·3
Normal minimum temperature in °F. . . .	75·7	81·2	80·5	79·3	75·2	63·7	51·7	44·4
Normal rainfall in inches .	0·64	2·53	8·20	6·94	4·24	0·48	0·11	0·65
Normal relative humidity (per cent) . . .	39	52	72	78	74	61	65	76
Ambala								
Normal maximum temperature in °F. . . .	103·7	102·7	95·4	93·1	93·5	92·1	81·9	72·1
Normal minimum temperature in °F. . . .	75·3	80·3	79·1	77·9	74·9	61·4	49·9	43·1
Normal rainfall in inches .	0·87	3·75	7·35	7·70	4·60	0·75	0·28	0·57
Normal relative humidity (per cent) . . .	43	59	79	84	79	68	73	80
Sialkot								
Normal maximum temperature in °F. . . .	102·4	105·1	97·7	94·5	94·9	91·9	80·8	69·3
Normal minimum temperature in °F. . . .	74·4	80·7	79·9	78·3	73·8	62·1	49·6	42·2
Normal rainfall in inches .	1·13	2·46	7·86	8·91	3·37	0·3	0·11	0·66
Normal relative humidity (per cent) . . .	42	49	75	83	76	66	75	87
Rawalpindi								
Normal maximum temperature in °F. . . .	97·9	103·6	97·9	93·9	93·4	88·8	77·5	66·8
Normal minimum temperature in °F. . . .	68·3	75·7	76·8	75·4	69·1	56·6	44·2	37·4
Normal rainfall in inches .	1·24	2·24	7·66	9·14	3·46	0·51	0·26	1·10
Normal relative humidity (per cent) . . .	41	45	68	77	69	59	65	75

TABLE IV—*contd.*

	May	June	July	August	September	October	November	December
Lahore								
Normal maximum temperature in °F. . . .	103·9	106·2	99·9	97·3	97·5	94·6	83·4	72·9
Normal minimum temperature in °F. . . .	71·8	78·7	79·7	78·4	72·7	59·2	46·8	39·8
Normal rainfall in inches .	0·70	1·68	5·48	5·35	2·36	0·25	0·07	0·36
Normal relative humidity (per cent) . . .	36	47	67	72	65	52	60	81
Hissar								
Normal maximum temperature in °F. . . .	106·5	106·4	99·8	96·5	96·8	94·2	84·6	74·1
Normal minimum temperature in °F. . . .	77·1	82·5	81·4	79·0	74·6	63·7	50·3	42·8
Normal rainfall in inches .	0·59	1·27	4·24	5·43	3·01	0·84	0·03	0·29
Normal relative humidity (per cent) . . .	38	49	68	72	67	56	60	70
Lyallpur								
Normal maximum temperature in °F. . . .	102·3	106·1	101·8	97·9	97·4	92·7	81·3	69·9
Normal minimum temperature in °F. . . .	73·4	81·6	82·4	80·1	74·4	61·9	48·5	41·3
Normal rainfall in inches .	0·52	1·14	3·02	4·24	1·69	0·24	0·16	0·33
Normal relative humidity (per cent) . . .	38	47	64	71	65	59	68	80
Khushab								
Normal maximum temperature in °F. . . .	103·8	107·3	102·6	100·2	98·8	94·0	82·9	71·7
Normal minimum temperature in °F. . . .	76·7	82·5	82·5	81·4	76·1	63·3	50·2	41·6
Normal rainfall in inches .	0·79	1·37	3·64	3·22	1·31	0·17	0·08	0·45
Normal relative humidity (per cent) . . .	34	42	63	69	61	46	51	60
Montgomery								
Normal maximum temperature in °F. . . .	106·4	108·7	103·9	101·1	99·9	95·8	83·9	72·1
Normal minimum temperature in °F. . . .	77·5	83·9	83·9	81·8	75·8	63·4	51·7	42·6
Normal rainfall in inches .	0·35	0·88	2·22	3·28	1·53	0·06	0·07	0·30
Normal relative humidity (per cent) . . .	39	46	63	69	63	55	59	72

TABLE IV—*contd.*

	May	June	July	August	September	October	November	December
Multan								
Normal maximum temperature in °F. . . .	106·6	108·3	104·3	100·9	100·4	95·9	84·5	73·3
Normal minimum temperature in °F. . . .	78·3	84·7	84·5	82·5	77·7	65·6	53·7	45·1
Normal rainfall in inches .	1·35	0·62	2·02	1·98	0·41	0·05	0·07	0·22
Normal relative humidity (per cent) . . .	43	51	64	69	65	56	60	69
Cawnpore								
Normal maximum temperature in °F. . . .	105·7	102·6	93·7	90·4	92·3	91·8	84·5	76·0
Normal minimum temperature in °F. . . .	79·4	82·9	80·1	78·6	76·7	65·9	54·4	47·2
Normal rainfall in inches .	0·40	3·32	10·55	11·38	6·74	1·27	0·40	0·18
Normal relative humidity (per cent) . . .	45	60	81	86	80	63	65	76

A study of the meteorological data of the various stations shows that from June to October the maximum temperature all over the province is above the upper limit of the suitable temperature range, *viz.* 82°F. The minimum temperature from July to October, generally falls within the suitable range, *i.e.*, 82°F. to 75°F. or is below the lower limit of the suitable range, *viz.*, 75°F., except at Lyallpur, Khushab and Montgomery (from the Canal Colonies), where it is above 82°F. in July, and at Multan from the western Punjab, where it is above 82°F. both during July and August. During the month of June the minimum temperature is above 82°F. at several stations, namely, Hissar from the south-eastern region, Khushab and Montgomery from the Canal Colonies and Multan from western tract.

From the above it is evident that during the greater part of twenty-four hours the temperature does not fall within suitable range at any station in the province. However, in the zone of 'normal outbreaks', the temperature during twenty-four hours falls within or is near the suitable temperature range for longer periods than anywhere else in the province. In the zone of 'occasional outbreaks' it deviates further from the suitable range. In the zone of 'possible outbreaks' it is still less favourable and is very adverse in the zone of 'no outbreaks'. We shall compare the normal monthly maximum and minimum temperatures of one station from each zone with the suitable range, which we consider most favourable for the increase of this pest.

At Ludhiana, from the zone of 'normal outbreaks', the normal mean monthly maximum temperature is above 82°F., the upper limit of the optimum temperature range, by about 23°F. in June, 15°F. in July, 13°F. in August, 12°F. in September and 10°F. in October. The normal mean monthly minimum temperature falls within the suitable range during June, July, August, and September, but is below 75°F., the lower limit of optimum temperature range by about 11°F. in October.

The meteorological data for Hansi, which has been taken as representative of the zone of ' occasional outbreaks ', are not available. At Hissar, which is situated at a distance of about fifteen miles, there is an observatory and the meteorological data of the latter station may be taken as approximating the conditions at Hansi. At Hissar the normal mean monthly maximum temperature is above 82°F. by about 24°F. in June, 18°F. in July, 15°F. in August and September and 12°F. in October. The normal mean monthly minimum temperature is above 82°F. by about 1°F. in June, falls within the suitable range during July, August and September and is below 75°F. by about 11°F. in October.

At Lyallpur, from the zone of ' possible outbreaks ', the normal mean monthly maximum temperature is above 82°F. by about 24°F. in June, 20°F. in July, 16°F. in August, 15°F. in September and 11°F. in October. The normal mean monthly minimum temperature falls within the suitable range during June and August and is above 82°F. by 1°F. in July, and below 75°F. by about 1°F. and 13°F. during September and October respectively. Thus during July, the most critical month, when the initial attack starts, the temperature is mostly higher than the higher limit of the suitable range, *i.e.*, 82°F.

At Multan, from the zone of ' no outbreaks ', the normal mean monthly maximum temperature is above 82°F. by about 26°F. in June, 22°F. in July, 19°F. in August, 18°F. in September and 14°F. in October. The normal mean monthly minimum temperature falls within the suitable range only during September. During June and July, and August it is above 82°F. by about 3°F. and 1°F. respectively, while during October it is below 75°F. by about 9°F. Here the conditions of temperature are even more adverse than at Lyallpur.

It may be possible to test such a correlation between the incidence of this pest in other cotton-growing parts of the world, but it is outside the scope of this paper.

It will, however, be interesting to study the climatic conditions of Cawnpore (United Provinces), where this pest causes very heavy losses [Richards, 1927, 1928, 1929]. At Cawnpore the seasonal history of Pink Bollworm is very much the same as in the Punjab [Richards, 1924] and the period of cotton growing also corresponds to that in the Punjab [Trought and Afzal, 1930].

The climatic data of Cawnpore are also given in Table IV. A study of the temperature records show that at Cawnpore the conditions for the increase of the pest are more favourable than they are anywhere in the Punjab. The normal mean monthly maximum temperature is above 82°F. by about 21°F. in June, 12°F. in July, 8°F. in August, 10°F. in September and October.

The normal mean monthly minimum temperature is above 82°F. by 1°F. in June, falls within the optimum range during July, August and September, and is below 75°F. by about 9°F. in October.

Fig. 2 represents graphically the normal meteorological data of the five stations discussed above, as also the suitable range of temperature for the procreation of the pest. Table V shows the deviation of the normal monthly maximum and minimum temperatures of these stations from optimum conditions.

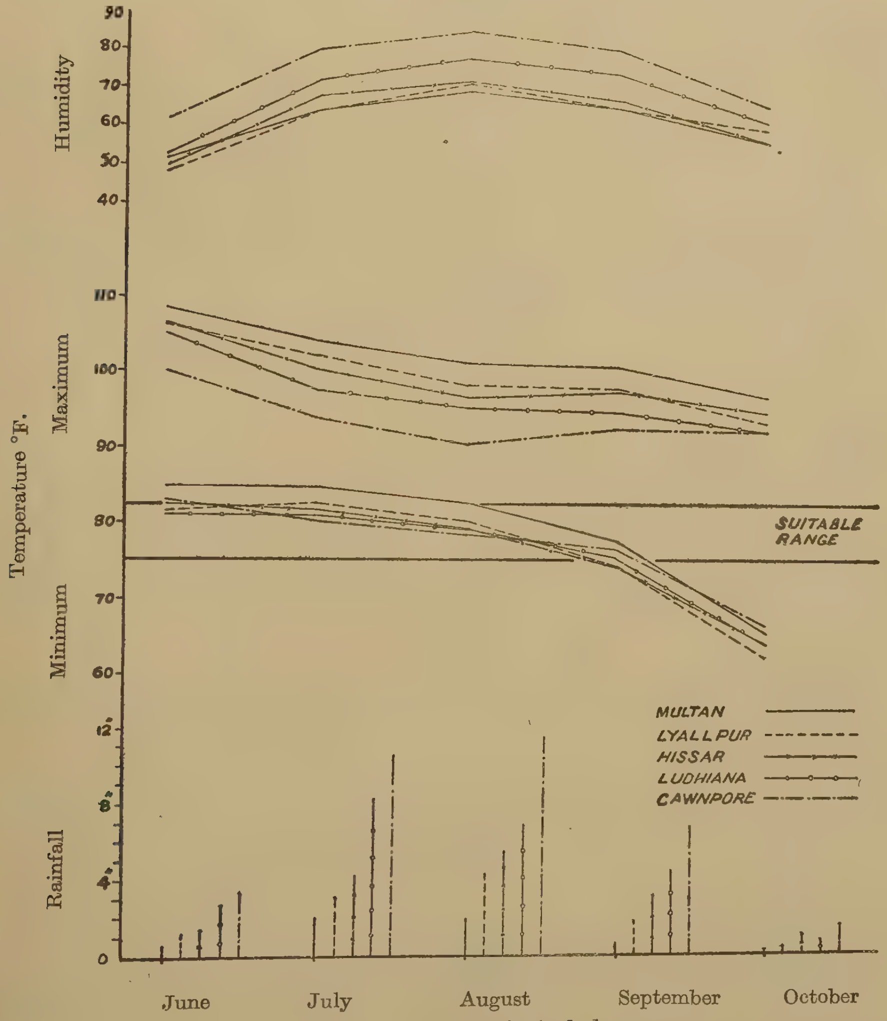


Fig. 2. Meteorological data

TABLE V

Deviation of the normal mean monthly maximum and minimum temperatures from the suitable range, 75°F.-82°F.(±)

Stations	June		July		August		September		October	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Cawnpore	+21	+1	+12	.. *	+8	..	+10	..	+10	—9
Ludhiana	+23	..	+15	..	+13	..	+12	..	+10	—11
Hissar	+24	+1	+18	..	+15	..	+15	..	+12	—11
Lyallpur	+24	..	+20	+1	+16	..	+15	—1	+11	—13
Multan	+26	+3	+22	+3	+19	+1	+18	..	+14	—9

*Denotes that the temperature falls within suitable range.

From what has been stated above it appears that broadly speaking the four zones, into which the Punjab has been divided on the basis of the intensity of Pink Bollworm attack, represent four sets of climatic conditions. It must, however, be remembered that one zone merges into another and there is no definite line of demarcation. Besides, (*i*) the incidence of Pink Bollworm has been studied from a limited number of places and (*ii*) such detailed meteorological data as would permit one to arrive at definite conclusions are not available except from a few stations.

In the Punjab, however, temperature is correlated with rainfall, the latter decreases as we proceed from the Himalayas to the desert of Rajputana and Sind and the Suleman range of barren hills. With fall in rainfall the temperature rises. Rainfall has been recorded at a large number of stations in the province and taking this as an index of the climatic complex we have an alternative correlation between rainfall and the incidence of Pink Bollworm attack.

Table VI gives the normal summer rainfall as also the normal annual rainfall of over sixty stations of the province. A study of the distribution of rainfall and the available records of the incidence of the pest show that generally :—

(*a*) In places where the rainfall from June to October is over fifteen inches, the percentage of green bolls attacked is over fifteen.

(*b*) In places where the rainfall is between eleven and fifteen inches, the percentage of green bolls attacked is over five and up to fifteen.

(*c*) In places where the rainfall is over eight and up to eleven inches, the percentage of green bolls attacked is above one andup to five.

(*d*) In places where the rainfall is eight inches or less, the percentage of green bolls attacked is one or less.

TABLE VI

Normal (annual and summer) rainfall in inches

Serial No.	District	Tehsil	Annual	June-October (Summer)
1	Kangra	Kangra	73·67	60·97
		Nurpur	60·74	47·51
		Palampur . . .	101·34	81·86
		Dera	52·44	41·87
		Hamirpur . . .	50·63	40·18
2	Gurdaspur . . .	Pathankot . . .	46·36	36·00
		Gurdaspur . . .	33·86	26·01
		Shakargarh . . .	34·83	26·61
		Batala	27·56	21·10
3	Rawalpindi . . .	Murree	56·90	36·73
		Kahuta	40·96	28·46
		Rawalpindi . . .	32·57	21·13
		Gujarkhan . . .	29·62	19·72
4	Ambala . . .	Nariangarh . . .	38·97	33·08
		Jaghadhari . . .	36·04	30·30
		Ambala	31·55	25·75
		Ropar	29·16	23·34
		Kharar	28·66	23·05
5	Hoshiarpur . . .	Una	36·22	28·74
		Hoshiarpur . . .	35·51	27·63
		Dasuya	32·46	25·07
		Garhshankar . . .	30·58	23·86
6	Sialkot . . .	Sialkot	32·23	23·83
		Pasrur	27·98	20·92
		Daska	24·69	18·28
7	Karnal . . .	Karnal	29·38	24·37
		Kaithal	18·55	15·08
		Thanesar. . . .	26·20	21·85
		Panipat	23·54	20·10
8	Gujrat . . .	Kharian	28·07	20·22
		Gujrat	26·33	18·73
		Phalia	20·30	14·34
9	Jullundur . . .	Nawa Shahar . . .	27·90	22·10
		Jullundur . . .	26·96	20·74
		Phillaur	24·16	19·10
		Nikodar	22·47	17·85

TABLE VI—*contd.*

Serial No.	District	Tehsil	Annual	June-October (Summer)
10	Ludhiana	Ludhiana	26·21	20·71
		Samrala	26·94	22·12
		Jagraon	21·01	16·91
11	Jhelum	Jhelum	26·06	18·17
		Chakwal	19·12	12·55
		Pind Dadankhan	17·08	12·17
12	Gurgaon	Gurgaon	25·12	21·89
		Nuh	24·02	21·10
		Palwal	23·95	21·03
		Ferozepur	23·51	21·10
		Balbgarh	23·04	19·78
		Rewari	20·19	17·60
13	Attock	Feteh Jang	25·09	15·47
		Talagang	19·24	12·30
		Pindigheb	18·10	11·19
14	Amritsar	Amritsar	23·54	18·27
		Tarn Taran	22·24	17·47
		Ajnala	20·71	15·85
15	Gujranwala	Gujranwala	23·45	17·39
		Wazirabad	21·24	15·59
		Hafizabad	17·52	12·67
16	Rohtak	Sonepat	23·00	19·68
		Gahana	20·56	17·19
		Jhajjar	19·70	16·66
		Rohtak	19·68	16·51
17	Ferozepore	Zira	18·89	15·09
		Ferozepur	17·78	13·55
		Moga	17·55	13·82
		Muktsar	12·39	9·98
		Fazilka	11·08	8·35
18	Lahore	Lahore	18·08	13·81
		Kasur	15·52	12·12
		Chunian	13·66	10·96
19	Hissar	Bhiwani	16·59	13·94
		Hansi	15·44	12·53
		Hissar	15·98	12·91
		Fatehabad	13·95	11·45
		Sirsa	13·54	10·96

TABLE VI—*contd.*

Serial No.	District	Tehsil	Annual	June-October (Summer)
20	Sheikhupura	Sheikhupura	15·33	11·80
21	Sargodha	Sargodha	15·14	10·69
		Shahpur	13·96	9·23
		Khushab	12·37	8·18
22	Lyallpur	Jaranwalla	15·22	12·08
		Lyallpur	13·08	10·00
		Samundri	10·48	6·94
		Toba Tek Singh	9·31	6·78
23	Jhang	Chiniot	12·02	8·72
		Jhang	10·17	7·30
		Shorkot	8·57	6·30
24	Mianwali	Mianwali	11·83	7·22
		Isakhel	9·89	5·36
		Bhakkar	8·07	5·51
25	Montgomery	Montgomery	10·14	7·73
		Dipalpur	9·54	7·17
		Okara	9·69	7·10
		Pakpattan	8·82	6·83
26	Muzzafargarh	Leiah	7·63	5·22
		Muzzafargarh	5·95	4·08
		Alipur	5·69	4·25
27	Multan	Multan	6·79	4·76
		Kabirwala	6·28	4·55
		Mailsi	6·05	4·18
		Shujabad	5·20	3·81
		Lodhran	5·18	3·71
28	Dera Ghazi Khan	Sanghar	7·00	4·11
		D. G. Khan	5·95	3·63
		Jampur	4·84	3·36
		Rajanpur	3·83	2·22

Fig. 3 gives the division of the Punjab into four zones according to the rainfall. These zones in general support our thesis, but there are some exceptions. Thus at Gujranwala, which records over fifteen inches of rainfall, the attack is less than fifteen per cent and lower than that of the zone of 'normal outbreaks' in which this locality lies. At Ferozepore, where the rainfall is only 13·6 inches the attack is over fifteen per cent, and similar is the case with Dera Ghazi Khan, where the rainfall is only 3·6 inches but the attack over one per cent.

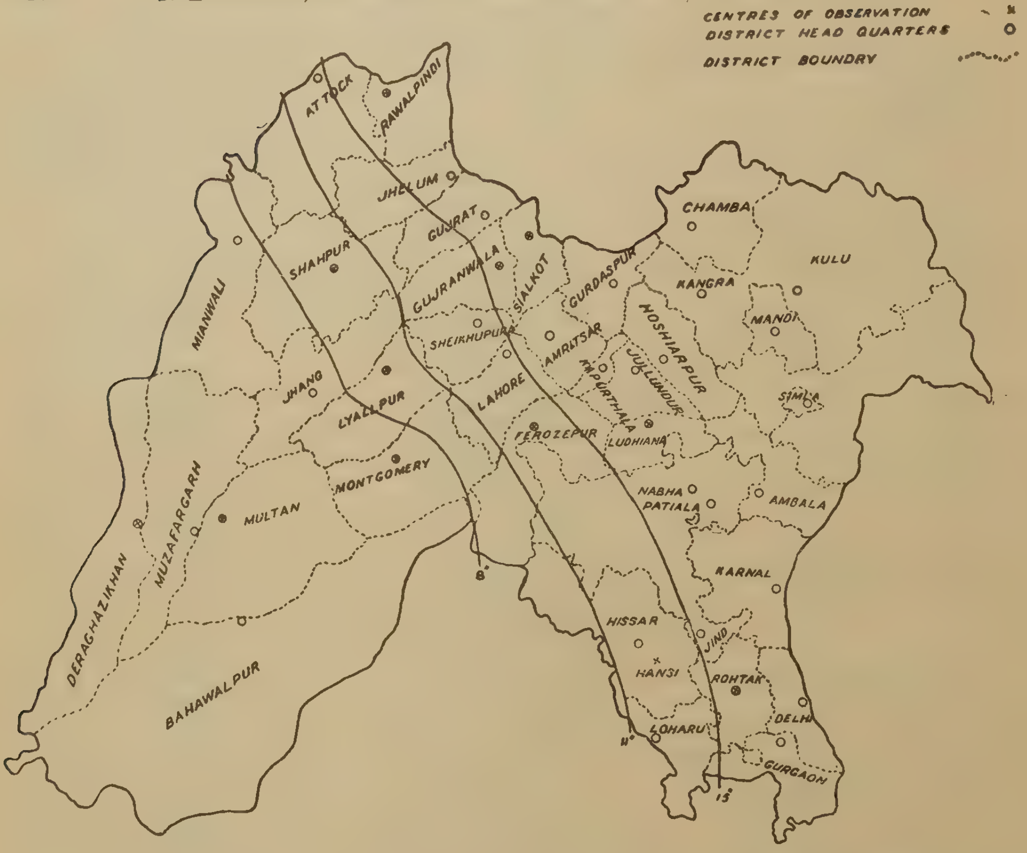

CENTRES OF OBSERVATION — ×
DISTRICT HEAD QUARTERS O
DISTRICT BOUNDRY
ATTOCK
RAWALPINDI
JHELUM
GUJRAT
CHAMBA
KULU
SHAHPUR
GUJRANWALA
SIALKOT
GURDASPUR
KANGRA
MANDI
MIANWALI
SHEIKHUPURA
AMRITSAR
HOSHIARPUR
KAPURTHALA
JULLUNDUR
JHANG
LYALLPUR
LAHORE
SIMLA
FEROZEPUR
LUDHIANA
MONTGOMERY
NABHA
PATIALA
AMBALA
MUZAFARGARH
MULTAN
KARNAL
DERAGHAZIKHAN
HISSAR
JIND
HANSI
ROHTAK
BAHAWALPUR
DELHI
LOHARU
GURGAON
8°
11°
15°

Fig. 3. Map of the Punjab, showing the distribution of summer rainfall

There may be several reasons for these slight fluctuations. At Ferozepur the attack is higher probably because of the nearness of the Grey Canal system and the accumulation of flood water during the months of July and August, that increases locally the atmospheric humidity and thereby affords more favourable environment. At Dera Ghazi Khan the nearness of the rivers probably affects the climate in the same way as at Ferozepur.

Besides these, there may be small areas, where the effects of climate may be offset, as shown also by Cooks [1929], by local conditions of soil, nearness of the water table, slope or other physiographic and edaphic factors, which, with the available data, it is not possible to mark out. These fluctuations, however, are not such as to go against our main thesis.

The yearly fluctuations in the incidence of Pink Bollworm at different stations are also probably the consequence of climatic variations, but it is not possible to develop a close correlation at the present stage of our knowledge. The ecological studies of Pink Bollworm have not advanced sufficiently to enable us to determine the exact influence of climatic conditions on the emergence of moths, development of their gonads, their oviposition and, in fact, their life-cycle as a whole.

We wish to make it clear that it is not intended to establish a direct correlation between rainfall and Pink Bollworm incidence. We have taken rainfall as an index of climatic conditions in the Punjab, and we are well aware that this may not apply to other parts of the globe.

In the zones of ‘ no outbreaks ’ and the zone of ‘ possible outbreaks ’ the applications of control measures usually is unnecessary, while in the zones of ‘ occasional ’ and ‘ normal outbreaks ’ the problem of control deserves consideration.

Further, one has to watch very carefully the progress of the pest. Will this pest ever get adapted to the climatic conditions of the Canal Colonies ? Or is the climate of the irrigated tracts changing on account of waterlogging, etc., sufficiently to become suitable for this pest ? In future, investigators will have to study these problems.

V. SUMMARY

The distribution and the incidence of *P. gossypiella* in the Punjab have been studied by the examination of green bolls from twelve stations.

The results obtained show that :—

(1) the attack on green bolls starts from the time they are available and increases with the progress of the season,

(2) the intensity of attack varies from year to year, the same locality showing wide fluctuations during different years, and

(3) the pest is serious in certain parts of the province and negligible in others.

On the basis of the normal incidence of *P. gossypiella* the province may broadly be divided into four zones as follows :—

(*i*) Zone of ‘ normal outbreaks ’ where over fifteen per cent of the green bolls produced are attacked, situated to the east of the fifteen-inch rainfall line.

(*ii*) Zone of ‘ occasional outbreaks ’ where over five and up to fifteen per cent of the green bolls produced are attacked, situated between eleven and fifteen inches lines.

(*iii*) Zone of ‘ possible outbreaks ’ where over one and up to five per cent of the green bolls are attacked, situated between eight and eleven-inch rainfall lines.

(*iv*) Zone of ‘ no outbreaks ’ where one or less than one per cent of the green bolls are attacked, and which lies west of eight-inch rainfall line.

Generally speaking in places where the attack is high, the climate is mild and humid and thus favourable for the procreation of the pest, while in places of low attack the climate is hot and dry and unfavourable for the multiplication of the pest.

Rainfall has been taken as an index of the climatic complex and a correlation between rainfall and incidence of pest has been attempted.

REFERENCES

Afzal Husain, M. (1930). *Ann. Rept. Dept. Agric. Punjab, Pt. II*, pp. 141-142.

Afzal Husain, M., Haroon Khan, M. and Nazir Ahmad (1935). *Current Sci.* 3, 304-305.

Ballard, E. (1921). *Rept. Proc. 4th Ent. Meeting, Pusa*, pp. 70-83.

Bindra, Sohan Singh (1928). *Mem. Dept. Agric. Ind.* (*Ent. Ser.*) **10**, No. 6.

Bodenheimer, F. S. (1928). *Z. Angew. Ent.* **12**, 91-122.

Cook, W. C. (1929). *Ecology* **10**, 282-293.

Entomological Section (1923). *Min. Agric. Egypt Tech. and Sci. Serv. Bull.* **27**, 1-19.

Gough, L. H. (1917). *Min. Agric. Egypt Bull.* **13** [Quoted from Ballou, H. A. (1920) The Pink Bollworm (*Gelechia gossypiella* Saunders) 69.]

——— ——— (1919). *Rept. Proc. 3rd Ent. Meeting, Pusa*, pp. 482-493.

Hunter, W. D. and Pierce, W. D. (1912). *U. S. Dept. Agric. Bull.* **114** [Quoted from Uvarov, B. P. (1931). *Trans. Ent. Soc.* **79**, 156.]

Jhonston, H. B. (1929). *Welcome Trop. Res. Lab. Ent. Sec. Bull.* **26**, 7-8.

Kirkpatrick, T. W. (1923). *Min. Agric. Egypt Bull.* **35**, 1-106.

——————— (1930). *Welcome Trop. Res. Lab. Ent. Sec. Bull.* **31**, 48-49.

Loftin, U. C.; Mckinney, K. B. and Hanson, W. K. (1921). *U. S. Dept. Agric. Bull. No.* **918**, 19-20.

Packard, C. M. (1929). *Trans. 4th Int. Congr. Ent.* (*Ithaca*) 2, 181-190.

Richards, P. B. (1924). *Agric. J. Ind.* **19**, 373-578.

——————— (1927). *Ann. Rept. United Prov. Dept. Agric.*, 42.

——————— (1928). *Ann. Rept. United Prov. Dept. Agric.*, 12.

——————— (1929). *Ann. Rept. United Prov. Dept. Agric.*, 60.

Rogers, L. (1928). *Proc. Roy. Soc.* (*B*) **103**, 42-72.

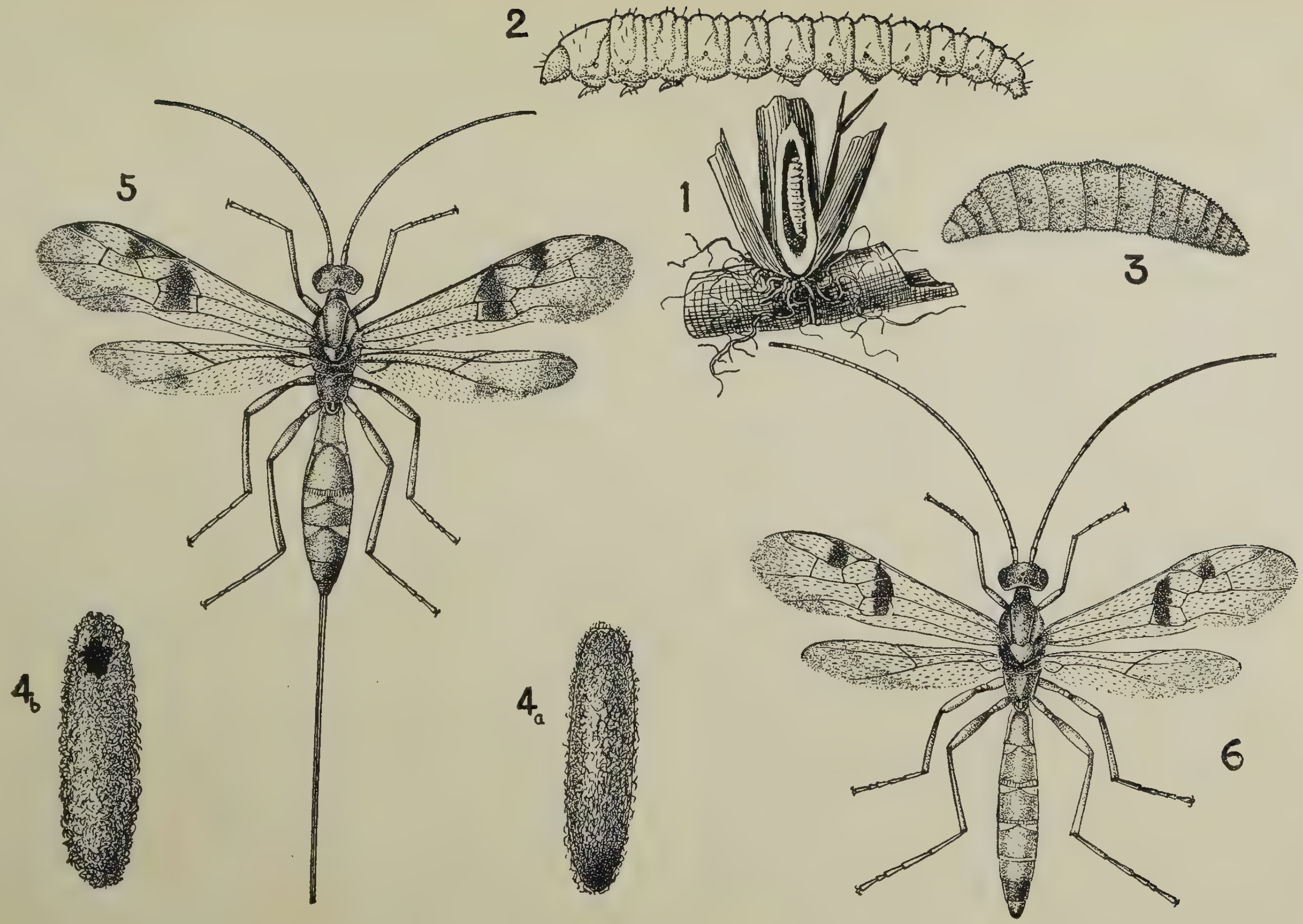
Rude, C. S. and Smith, Charles (1932). *J. Econ. Ent.* **25**, 772-776.

Trought, T. (1928). *Emp. Cot. Growing Rev.* **5**, 228-238.

Trought, T. and Afzal, M. (1930). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **17**, No. 5.

Uvarov, B. P. (1931). *Trans. Ent. Soc.* **79**, 1-187.

Williams C. B. (1926). *Min. Agric. Egypt Bull.* **67** 1-12.



1. The Root-borer larva *in situ* ; 2. The Root-borer larva (enlarged) ; 3. The full-grown larva of the parasite (enlarged) ; 4*a*. The cocoon (enlarged) ; 4*b*. The cocoon showing irregular hole made by the adult parasite when coming out (enlarged) ; 5. The female parasite (enlarged) ; 6. The male parasite (enlarged).

ENTOMOLOGICAL NOTE

M9.

A NOTE ON *STENOBRACON DEESAE* (CAM.), A NEW PARASITE OF THE ROOT-BORER OF SUGARCANE

BY

E. S. NARAYANAN, M.A.

Assistant to Imperial Entomologist, New Delhi

(Received for publication on 1st March 1937)

(With Plate IX)

STENOBRACON DEESAE (CAM.) (Plate IX, figs. 5 and 6) belongs to the subfamily *Vipioninae* of the family *Braconidae*. The parasite was originally described as *Bracon deesae* by Cameron [1902] from specimens collected at Deesa, Bombay Presidency. According to Ramakrishna Ayyar [1928], who called it *Stenobracon deesae* (Cam.), the parasite is common at Coimbatore and also occurs in Bellary, Anantapur, and Kurnool district on *juar* (*Andropogon Sorghum*) and *marua* (*Eleusine coracana*) fields. The same author [Ramakrishna Ayyar, 1923] also reared the parasite from *Chilo simplex* Butl., the well-known borer of *juar*. In the Punjab [Chopra, 1927] it has been reared from *Euproctis lunata* Walk. The present author bred it from the Root-borer of sugarcane, *Emmalocera depressella* Swinh. at Pusa for the first time in 1935. The percentage of parasitism observed in the field in 1935 and 1936 varied from three to five.

The parasite was seen in small numbers in the sugarcane fields from the last week of April up to the beginning of July. It is very active and though extremely swift in its movements it can be readily recognised in the field because of its bright yellow colour and its long ovipositor. The parasite alights now and then and moves about under the base of young cane, evidently in search of its prey. The long ovipositor, which is equal in length to the insect's body, doubtless aids it in laying the eggs on the deeply situated Root-borer larva. From observations made in the fields it is clear that the success of parasitisation depends upon the success of the endeavour of the parasite to locate the entrance of *Emmalocera depressella* Swinh. caterpillars ; for if it succeeds then it can introduce its ovipositor and locate the host larva easily.

The full-grown parasitic larva (Plate IX, fig. 3) is of the typical braconid type and is 12·5 mm. long and 3 mm. broad across the thorax. It is greyish brown in colour. The head and the thirteen post-cephalic segments are clearly marked. There are nine pairs of spiracles, the first pair in the mesothorax and the next eight pairs in the first eight segments of the abdomen. The larval period in the host takes about twenty-two to twenty-five days and the pupal period ten days during the monsoon months. If unfed the parasite dies in thirty-six hours. If fed with sugar solution the female lives for more than a week, even ten days, in a glass rearing jar. The male dies within thirty-six hours even if fed.

REFERENCES

Cameron, P. (1902). *J. Bombay Nat. Hist. Soc.* **14**, 433-434.

Chopra, R. L. (1928). *Ann. Rept. Govt. Ent. Punjab, Lyallpur*, 1927, **I**, Pt. 2, 47.

Ramakrishna Ayyar, T. V. (1923). *Rept. Proc. 5th Ent. Meet., Pusa*, 263.

———————— (1928). *Mem. Dept. Agric. Ind.* (*Ent. Ser.*) **10**, No. 3.

NOTICE

CHANGES IN TITLES OF SOME OF THE IMPERIAL AGRICULTURAL BUREAUX

In pursuance of the recommendations of the British Commonwealth Scientific Conference, 1936, the Executive Council of the Imperial Agricultural Bureaux have decided to adopt the following revised titles for certain bureaux with effect from the first January 1938 :—

(*a*) The Imperial Bureau of Plant Breeding and Genetics (at Cambridge).

(*b*) The Imperial Bureau of Pastures and Forage Crops (at Aberystwyth).

(*c*) The Imperial Bureau of Horticulture and Plantation Crops (at East Malling).

(*d*) The Imperial Bureau of Animal Breeding and Genetics (at Edinburgh).

(*e*) The Imperial Bureau of Agricultural Parasitology (Helminthology) (at St. Albans).

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Periodical Abstracts

Lists of publications and papers on Soil Science published in the Empire Overseas in—

	Price s.	d.
1933	1	0
1934	1	0
Soil Research in the British Empire published during 1935	1	0
Lists of Publications relating to Soils and Fertilisers—		
Published monthly, per annum, post free	10	0
Monthly Letters—		
Free to recipients, within the British Empire, of 'Publications relating to Soils and Fertilisers.' Subscription, outside the Empire, per annum	4	0
Recent Developments in Soil Analysis—		
Quarterly Supplement to the above publications. Separate copies each	0	6

Occasional Papers

	s.	d.
Technical Communications—		
34. Tropical Soils in relation to Tropical Crops	2	6
Annual Report : For the year 1934-35	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions (by the late Sir J. B. Harrison)	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1931-34	25	0

II. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL HEALTH, VETERINARY RESEARCH LABORATORY, NEW HAW, WEYBRIDGE, SURREY

Abstracting Journal

	s.	d.
The Veterinary Bulletin—		
1931. Vol. 1. Quarterly (1st Number, April)	7	6
Annual subscription	20	0
Subsequent volumes. Monthly (1st Number, January)	5	0
Annual subscription (postage paid)	40	0

Indexing Publication

	Price s.	d.
Index Veterinarius—Four issues a year. First issue April 1933— Annual subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed	100	0

III. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL NUTRITION, ROWETT RESEARCH INSTITUTE, BUCKSBURN. ABERDEEN

Journal

Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)—

	s.	d.
Subscription per volume of 4 numbers	42	0
Per single number	13	0

Occasional Papers

Technical Communications—

	s.	d.
7. Wheat: Pre-eminence as a Cereal Food, Nutritive Value; Relation to Health and Disease	1	0

Occasional Communications—

1. The Effect of Climate on the Composition of Pasture Plants.

IV. OBTAINABLE FROM THE IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS PLANT BREEDING INSTITUTE, SCHOOL OF AGRICULTURE, CAMBRIDGE

Journal

Plant Breeding Abstracts—

	s.	d.
Quarterly. Annual Subscription	15	0
Single copies	5	0

Occasional Papers

	s.	d.
Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932-1935. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication of the Imperial Bureaux of Plant Genetics)	10	0
Bibliographical Monographs—		
The Experimental Production of Haploids and Polyploids	5	0
Breeding Resistant Varieties, 1930-33 (Supplement)	2	0
An Outline of Cytological Technique for Plant Breeders	1	6

V. OBTAINABLE FROM THE IMPERIAL BUREAU OF PASTURES AND FORAGE CROPS, WELSH PLANT BREEDING STATION, AGRICULTURAL BUILDINGS, ALEXANDRA ROAD, ABERYSTWYTH, WALES

Journals

	Price s.	Price d.
Herbage Abstracts—		
Quarterly. Annual subscription	15	0
Single numbers	5	0
Herbage Reviews—		
Subscription is at present—Vol. 1 (1933), Vol. 2 (1934), Vol. 3 (1935), Vol. 4 (1936)—included in that to Herbage Abstracts		

Occasional Papers

	s.	d.
Bulletins—		
19. Production of Grass Seed	5	0
20. Insects and Other Pests Injurious to the Production of Seed in Herbage and Forage Crops, H. F. Barnes	2	6
21. The Influence of Climatic Conditions on Type Composition. Nils Sylvén	1	0
22. Technique of Grass Seed Production at Welsh Plant Breeding Station. Gwilym Evans	5	0
23. Production of Legume Seed	5	0
24. Collection of Native Grass Seed in the Great Plains, U. S. A. F. J. Crider and M. M. Hoover	2	0

VI. OBTAINABLE FROM THE IMPERIAL BUREAU OF HORTICULTURE AND PLANTATION CROPS. EAST MALLING RESEARCH STATION, EAST MALLING, KENT

Journal

	s.	d.
Horticultural Abstracts—		
A quarterly abstract publication of current horticultural literature—		
Annual subscription	15	0
Single copy	4	0

Technical Communications

	s.	d.
8. Horticultural Aspects of Woolly Aphis Control together with a Survey of the Literature. R. M. Greenslade	2	6

Occasional Papers

	s.	d.
3. Annotated Bibliography on Bitter-Pit. 1934	1	6
Other Publications—		
Index to Volumes I—X of the *Journal of Pomology and Horticultural Science*, 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science*. Available from the Bureau	5	0
Old and New Standpoints on Senile Degeneration, 1931. By A. P. C. Bijhouwer	0	6

VII. Obtainable from the Imperial Bureau of Animal Breeding and Genetics, Institute of Animal Genetics, University of Edinburgh, King's Buildings, West Mains Road, Edinburgh

Journal

	Price s.	d.
Animal Breeding Abstracts (Quarterly). Commencing April, 1933. Annual subscription	**15**	**0**

Occasional Papers

	s.	d.
Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0

VIII. Obtainable from the Imperial Bureau of Agricultural Parasitology (Helminthology), Institute of Agricultural Parasitology, Winches Farm Drive, Hatfield Road, St. Albans, Herts

Journals

	s.	d.
Bibliography of Helminthology. For the year 1933—		
Library edition, bound in cloth	**10**	**6**
Stiff paper cover only	**8**	**0**
Helminthological Abstracts. (Issued in five or six parts per volume, each volume covering the literature of a single year.) Subscription per volume, payable in advance	**30**	**0**
Completed volumes bound in cloth	**32**	**0**

Occasional Papers

	s.	d.
The Effects of some Natural Factors on the Second Ecdysis of Nematode Infective Larvae. By G. Lapage. 25 pp.	**4**	**0**
Notes and Memoranda—		
11. Recent Developments in the Control of *Heterodera marioni*. 6 pp	**1**	**6**

Publications issued by the Imperial Institute of Entomology, 41, Queen's Gate, London, S. W. 7

	s.	d.
Bulletin of Entomological Research.—Published quarterly and containing original articles on Economic Entomology. Issued post-free. Annual subscription (payable in advance)	30	0

Review of Applied Entomology.—Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series. Series ‘A’ dealing with insect and other arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin, Series ‘B’ dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post-free.

	Series ‘A’	Series ‘B’
	s.	*s.*
Annual subscription (payable in advance)	30	15
Vol. XXIII (1935)	42	21

Zoological Record—Part Insecta.—Published annually about July in each year and containing as complete a record as possible of the literature of the previous year chiefly from the systematic standpoint.

	s.	*d.*
Annual subscription (including postage)	15	6
Report of the Fourth Imperial Entomological Conference, 19—27th September 1935	4	0

PUBLICATIONS OBTAINABLE FROM THE IMPERIAL MYCOLOGICAL INSTITUTE, KEW, SURREY

Journal

Review of Applied Mycology.—Annual subscription, 12 monthly parts, with title page and index (post-free)	21	0
Single part	2	0
Title page and index	3	0
Report on the Third Imperial Mycological Conference, 1934	2	0

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian postage]

1. Agriculture and Live-stock in India

ICAR. 1 A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the tropics. (Established 1931.) Published in January, March, May, July, September and November. Prepayable subscription Rs. 6 or 9*s*. 9*d*. per annum. Price per part Rs. 2 or 3*s*. 6*d*. Volumes I to VII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5 A bi-monthly scientific journal of agriculture and the allied sciences, mainly devoted to the publication of the results of original research and field experiments. (Established 1931.) Published in February, April, June, August, October and December. Prepayable subscription Rs. 15 or 24*s*. per annum. Price per part Rs. 3 or 5*s*. 3*d*. Volumes I to VII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6 A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931.) Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s*. 9*d*. Price per part Rs. 2 or 3*s*. 6*d*. Volumes I to VII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10-1 No. 1. The Fungi of India, by E. J. Butler, C.I.E., D.Sc., M.B., F.R.S. and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s*.

ICAR. 10-2 No. 2. Life-histories of Indian Microlepidoptera, Second Series : Alucitidae (Pterophoridae, Tortricina and Gelechiadae), by T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s*. 6*d*.

ICAR. 10-3 No. 3. The Open-Pan System of White-Sugar Manufacture, by R. C. Srivastava, B.Sc. (1935, 2nd edition). Price Rs. 3-2-0 or 5*s*. 6*d*.

ICAR. 10-4 No. 4. Life-histories of Indian Microlepidoptera : Cosmopterygidae to Neopseustidae, by T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1933). Price Rs. 4-8-0 or 7*s*. 6*d*.

ICAR. 10-5 No. 5. The Bombay Grasses, by E. J. Blatter, S.J., Ph.D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. Price Rs. 20-12-0 or 32*s*. 6*d*.

ICAR. 10-6	No. 6. Helminth Parasites of the Domesticated Animals in India, by G. D. Bhalerao, M.Sc. Price Rs. 7-12-0 or 13*s*. 3*d*.
ICAR. 10-7	No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng. and the Isolation of Types Resistant to the Disease, by W. McRae, M.A., D.Sc. (Edin.), F.L.S. and F. J. F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s*. 3*d*.
ICAR. 10-8	No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy, by C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s*. 9*d*.
ICAR. 10-9	No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah Shell Oil Storage and Distributing Company of India, Ltd., by C. P. G. Wade. Price Rs. 3-14-0 or 6*s*. 6*d*.
ICAR. 10-10	No. 10. The Spotted Boll-worms of Cotton in South Gujarat, by B. P. Deshpande and N. T. Nadkarny. Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 10-11	No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus Muscles and the Formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations, by H. N. Chelva Ayyangar, G.M.V.C. Price Rs. 4-10 or 7*s*. 9*d*.
ICAR. 10-12	No. 12. The Fungi of India, Supplement I, by B. B. Mundkur (*In Press*).

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8-1	No. 1. List of Publications on Indian Entomology, 1930, by the Imperial Entomologist, Pusa. Price As. 14 or 1*s*. 6*d*.
ICAR. 8-2	No. 2. List of Publications on Indian Entomology, 1931, by the Imperial Entomologist, Pusa. Price As. 8 or 10*d*.
ICAR. 8-3	No. 3. List of Publications on Indian Entomology, 1932, by the Imperial Entomologist, Pusa. Price As. 12 or 1*s*. 3*d*.
ICAR, 8-4	No. 4. Host Plant Index of Indo-Ceylonese Coccidae, by S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. Price Re. 1-10-0 or 2*s*. 9*d*.
ICAR, 8-5	No. 5. List of Publications on Indian Entomology, 1933, compiled by the Officiating Imperial Entomologist, Pusa. Price As. 9 or 1*s*.
ICAR. 8-6	No 6. Bee-keeping, by C. C. Ghosh, B.A., F.E.S. (3rd Edition). Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8-7	No. 7. List of Publications on Indian Entomology, 1934, compiled by the Officiating Imperial Entomologist and the Imperial Entomologist, Pusa. Price Re. 1-2-0 or 2*s*.
ICAR. 8-8	No. 8. Selected Clinical Articles, Part I, by G. K. Sharma, and R. L. Kaura. Price As. 8 or 10*d*.
ICAR. 8-9	No. 9. Statistical Methods and their Application to Agronomy: A Bibliography, by K. K. Guha Roy. Price Rs. 2-2-0 or 4*s*.
ICAR 8-10	No. 10. Diseases of Sugarcane and Methods for their Control, by L. S. Subramaniam. Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8-11	No. 11. Tables of Standard Errors of Mendelian Ratios, compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell), and P. Krishna Rao, L.Ag. Price As. 12 or 1*s*. 3*d*.
ICAR .8-12	No. 12. List of Publications on the Botany of Indian Crops, Part II, for the Period 1928-32, by R. D. Bose. Price Rs. 3-6 or 5*s*. 9*d*.

ICAR. 8-13	No. 13. Two New Statistical Tables based upon Fisher's '*t*', by M. Vaidyanathan. Price As. 6 or 8*d*.
ICAR. 8-14	No. 14. List of Publications on Indian Entomology, 1935, compiled by the Imperial Entomologist, Pusa. Price Re. 1-4 or 2*s*.
ICAR. 8-15	No. 15. Selected Clinical Articles, Part II, by G. K. Sharma, R. L. Kaura, S. Ganapathy Iyer, G. S. Khan and S. Mangrulkar. Price Re. 1-4 or 2*s*.
ICAR. 8-16	No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders, by P. E. Lander, M.A., D.Sc., F.I.C., I.A.S. Price Rs. 3-14-0 or 6*s*. 9*d*.
ICAR. 8-17	No. 17. A Brief Survey of some of the Important Breeds of Cattle in India, by Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S. Price Rs. 2-0-0 or 3*s*. 6*d*.
ICAR. 8-18	No. 18. Milk Records of Cattle in Approved Dairy Farms in India, by K. P. R. Kartha, B. A. (*In Press*).
ICAR. 8-19	No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province, by Hem Singh Pruthi, M.Sc., Ph. D. (Cantab.), F.N.I. and H. N. Batra, B.Sc., Assoc. I.A.R.I. (*In the Press*).

6. Annual Reports of the Imperial Council of Agricultural Research

ICAR. 12-31	Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.
ICAR. 12-32	Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.
ICAR. 12-33	Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of stock).
ICAR. 12-34	Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Re. 1-8 or 2*s*. 6*d*.
ICAR. 12-35	Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.
ICAR. 12-36	Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.
ICAR. 12-37	Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Re. 1-2 or 2*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9-29	Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock).
ICAR. 9-31	Review of Agricultural Operations in India, 1929-31. Price Rs. 5 or 8*s*. 3*d*.
ICAR. 9-33	Review of Agricultural Operations in India, 1931-33. Price Rs. 5-12-0 or 9*s*. 6*d*.
	Agriculture and Animal Husbandry in India, 1933-34 and 1934-35.—
ICAR. 13-1-35	Part I.—Crop Production. Price Rs. 4-14 or 8*s*.
ICAR. 13-2-35	Part II.—Animal Husbandry. Price Re. 1 or 1*s*. 9*d*.
ICAR. 13-36	Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10-0 or 7*s*. 9*d*.

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2	Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 3	Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s*. 9*d*.

Miscellaneous

VRI. I	A Description of the Imperial Institute of Veterinary Research, Muktesar and its substation, the Imperial Veterinary Serum Institute, Izatnagar, by F. Ware, F.R.C.V.S. Price Re. 1-4-0 or 2*s*.
ARI. 7-187	The Production of Cigarette Tobacco by Flue-curing, by F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. and Kashi Ram. *Imp. Inst. Agri. Res. Pusa. Bull.* No. 187. Reprinted (1935). Price Re. 1 or 1*s*. 9*d*.
ICAR. 16	A Handbook of Statistics for Use in Plant Breeding and Agricultural Problems, by F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s*. 3*d*.

Copies of the above publications can be had from—

The Manager of Publications, Civil Lines, Delhi, and from any of the Agents, a list of whom will be found on the inside page of the front cover.

Purchasers not residing in Asia should obtain publications from the High Commissioner for India, India House, Aldwych, London.

NOTE.—When indenting please give only the symbol preceding the name of the publication.

GIPD--S 3—805 IC of AR—20.4-38—800.

CONTENTS

(VOL. VIII, PART III)

ERRATA

The Indian Journal of Agricultural Science,
Vol. 8, Part III, June 1938

Page 274, 1st column of the table, last item, *for* 'argodha' *read* 'Sargodha'.

Page 383, letterpress on the vertical axis of the graph should read "Per cent alkali — distilling constant".

ATION OF MUSTARD (A PRELIMINARY REPORT) (WITH PLATE X)	*D. Sen and S. C. Chakravarti*	245
PRELIMINARY STUDIES IN THE RESPIRATION OF SUGARCANE *IN SITU* (WITH FIVE TEXT-FIGURES)	*K. L. Khanna and P. C. Raheja*	253
SOIL UNIFORMITY TRIALS IN THE PUNJAB, I (WITH SEVEN TEXT-FIGURES)	*P. E. Lander, M.A., D.Sc., F.I.C., I.A.S.; Ramji Narain, Ph.D., D.Sc. and Azmat Singh, L. Ag.*	271
COMPARISON OF METHODS FOR THE ESTIMATION OF THE FURFURALDEHYDE YIELD OF SOILS AND COMPOSTS	*C. N. Acharya, M.Sc., Ph.D., A.I.C.*	309
PRUNING OF FRUIT TREES: THE EFFECT OF DORMANT PRUNING ON CROPPING AND VEGETATIVE VIGOUR OF *PHALSA* (*GREWIA ASIATICA*) (WITH PLATES XI-XIII AND ONE TEXT-FIGURE)	*Lal Singh, B.Sc. (Hons.), M.Sc. (Calif.) and Sham Singh, B.Sc. (Agri.-Pb.), Ph.D. (Bristol), F.R.H.S.*	319
STUDIES ON GROUNDNUT NODULE ORGANISM, I. ISOLATION OF STRAINS AND STUDY OF CULTURES (WITH ONE TEXT-FIGURE)	*T. Rajagopalan, B.A., M.Sc.*	331

		PAGE
STUDIES ON GROUNDNUT NODULE ORGANISM, II. LIFE-CYCLE OF THE ORGANISM (WITH PLATES XIV AND XV)	*T. Rajagopalan, B.A., M.Sc.*	349
STUDIES ON GROUNDNUT NODULE ORGANISM, III. PHYSIOLOGY OF THE ORGANISM: FERMENTATION CHARACTERISTICS (WITH THREE TEXT-FIGURES)	*T. Rajagopalan, B.A., M.Sc.*	357
STUDIES ON GROUNDNUT NODULE ORGANISM, IV. PHYSIOLOGY OF THE ORGANISM—INTERMEDIARY METABOLISM: CARBOHYDRATES AND NITROGEN (WITH SIX TEXT-FIGURES)	*T. Rajagopalan, B.A., M.Sc.*	379

REVIEW—

APPLIED MYCOLOGY AND BACTERIOLOGY 403

ORIGINAL ARTICLES

STUDIES IN INDIAN FIBRE PLANTS

No. 5. FURTHER STUDIES ON THE INHERITANCE OF CERTAIN CHARACTERS IN *HIBISCUS SABDARIFFA* L.

BY

R. B. DESHPANDE, M. Ag. (Bom.), Assoc. I.A.R.I.
Botanical Section, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 26th August 1937)

CONTENTS

	Page
I. Introduction	229
II. Technique of hybridization	231
III. Description of the parents and the F_1's	232
IV. Experimental results	233
A. Cross No. 1, *H. sabdariffa* var. *albus* × *altissima*	233
B. Cross No. 2, *H. sabdariffa* var. *ruber* × *altissima*	239
V. Summary	242
References	243

I. Introduction

The accidental introduction into India in 1927 of a new type of *Hibiscus*, the New Pusa hemp, *Hibiscus sabdariffa*, L. var. *altissima*, Wester [Khan, 1930], led to the investigations which form the subject matter of this paper. This plant which grows to a considerable height and has a straight, almost unbranched, stem, possesses the habit of *H. cannabinus*, L. and resembles *H. sabdariffa* in some morphological characters. The plant on being referred to Kew, Buitenzorg and the Royal Botanical Gardens, Calcutta, was unanimously identified as *H. sabdariffa*.

In order to study the affinity of this variety with those already known in India, a number of crosses were made in 1929-30 and 1930-31. It was also hoped that the crosses would yield strains combining the tall, unbranched habit of *altissima* with the smooth stem of the other *sabdariffa* types. This object has been achieved and a few plants from the most promising hybrids were sent to the Fibre Expert to the Government of Bengal for fibre tests and the fibre of one of them was reported to be superior to that of *altissima*.

This new variety, *altissima*, was crossed with two of the *sabdariffa* varieties, *viz.*, *albus* and *ruber* and also with some types of *H. cannabinus*. The results of these crosses, which are given in the statement below, show that the percentage of setting of capsules in the former was 53·8, all the capsules having viable seeds, while that in the latter was 44·4 none of the capsules having any viable seeds. The results thus show that the new variety is indeed more closely related to *H. sabdariffa* than to *H. cannabinus* and further confirm the identifications by the Botanical Gardens, Kew, Buitenzorg and Calcutta.

TABLE I

Results of crossing altissima *with* H. sabdariffa *and* H. cannabinus *types*

Cross	Year	No. of flowers polli-nated	No. of capsules formed	Per cent setting of capsules	No. of capsules having viable seeds	Percent-age of capsules having viable seeds
H. sabdariffa var. *albus* × *altissima* and reciprocal . . .	1929-30	79	32	40·5	32	100
Ditto . .	1930-31	55	29	52·7	29	100
H. sabdariffa var. *ruber* × *altissima* and reciprocal . .	1929-30	90	54	60·0	54	100
Ditto . .	1930-31	23	18	78·3	18	100
Total .		247	133	53·8	133	100
H. cannabinus types × *altissima* and reciprocal . .	1929-30	49	24	49·0	0	0
Ditto . .	1930-31	235	102	43·4	0	0
Total .		284	126	44·4	0	0

The previous investigations on inheritance in this plant (*H. sabdariffa*) [Howard and Howard, 1924], were restricted only to the colour characters in various plant organs, *viz.*, stem, leaf-veins, petiole, sepals, faded corolla, etc. In the present investigation, keeping the same genetical constitution as suggested by them for both *albus* and *ruber*, the parental types common to the investigations, this new variety has been analysed genetically for colour in stem, petiole, leaf-vein, and faded corolla, etc., and so far as these characters are concerned the new variety resembles the 'intermedius' of Howard and Howard [1924] except that it (the new variety) possesses the factor **F**, which produces pink colour in faded corolla and lacks $\mathbf{P}_1$, the factor for pink flush on the stem. Our results generally agree with those of the Howards. For the inheritance of leaf-lobe and hairiness of stem, new genetical formulæ have been proposed.

The study of the inheritance of stigma colour was discontinued because of the great deal of variation in the colour of stigmas even in the same plant. The F_2 of *ruber* × *altissima* was repeated because of discrepancies in the results for the character hairiness in the original cross.

II. Technique of hybridization

The size of the flower being large, the operations of emasculation and pollination are very simple. The flowers open in the morning some time after sunrise and begin to close after mid-day. Simultaneously with the opening of the flower, the anthers dehisce, and the stigmas, being just at the level of the staminal tube, get almost immediately pollinated. In *altissima*, however, the stigmas usually grow slightly higher than those in the other varieties of *H. sabdariffa*, which probably accounts for the small percentage of natural crossing in the former as compared with its almost total absence in the latter.

Emasculation.—The buds which seem likely to open next morning should be selected for emasculation. In such buds the folded corolla slightly peeps out of the calyx on the evening previous to their opening. With a sharp scalpel or a razor the clayx together with the folded corolla is cut out. This exposes the whole of the staminal tube and enables complete removal of the anthers either by means of a pair of forceps or scissors, or by merely moving the back of a scalpel-blade up and down on the staminal tube. If any anthers are crushed and are difficult to remove by a pair of forceps, a jet of water may be used, all traces of water being afterwards carefully removed by means of a piece of blotting paper. A small rubber syringe is quite satisfactory for getting a sufficiently strong jet. The emasculated buds should then be covered with muslin or paper bags.

Pollination.—For pollination, buds of the same stage of development as are used for emasculation should be selected and covered with a paper bag to keep out foreign pollen. Next morning (about 10 A.M.) when the anthers have dehisced (the time varies with the season and weather conditions) the flowers should be plucked and the corolla cut away to facilitate pollination. The pollen being sticky, it is necessary to rub the staminal tube gently over the stigmas of the emasculated flowers so as to fully cover them with pollen. The bags should be replaced and labels attached in the usual manner. The pollen from one flower is sufficient to pollinate a number of emasculated flowers.

Selfing.—When a large quantity of selfed seed is required the whole plant or some of its branches should be enclosed within a muslin bag. When individual flowers are to be selfed, small muslin or paper bags should be used. The latter are handy and are preferred to the former.

Ringing, as suggested by Kottur [1919] for cotton, has been tried, but the seed production in this case (*Hibiscus*) is scanty. Seccotine also has been tried with a fair amount of success. The defect with Seccotine is that in the rains, or on very heavy dewy mornings in winter it gets soft and there is danger of the corolla opening. Rubber solution has also been tried with good results, but on very hot mornings there is a chance of the solution becoming soft and yielding to the pressure of the opening corolla.

III. Description of the parents and the F_1's

Some of the characters of the parents, *viz.*, *albus*, *ruber*, and *altissima* and the F_1 populations are given in Table II.

Table II

The characters of the parents and the two F_1's

Characters	*Albus* parent	*Albus* × *Altissima*, F_1	*Altissima* parent	*Ruber* × *Altissima*, F_1	*Ruber* parent
Stem (colour and hairiness)	Green, smooth	Red, intermediate in hairiness	Green in early stages with red patches in leaf-axil and below petiole base, turning entirely red at maturity, hairy	Red, intermediate in hairiness	Red, smooth
Leaf-lobe .	Broad .	Narrow, intermediate in size	Narrow . .	Narrow, intermediate in size	Broad
Eye of corolla	Pale yellow	Red .	Red . .	Red . .	Red
Stigma .	Do. .	Deep red .	Very deep purple	Intermediate	Deep red with a purple tinge
Colour of faded corolla	Yellow .	Pale pink .	Pale pink .	Pink . .	Pink

It will be seen from the above table that the two F_1's are identical in all respects except in the stigma colour and colour of faded corolla which are a little lighter in the F_1 of *albus* × *altissima* than those in the other cross. The reciprocals were alike in both the crosses.

Slight, though not always distinguishable, difference could be found between the intensity of red colour in the stem of *ruber* and in that of the F_1 of *ruber* × *altissima*. The extent to which the stem of each was coloured varied. Actual measurements of the coloured to non-coloured portions of the stem in each case showed that in *ruber* the proportion of coloured to non-coloured portion of the stem was 2·58 : 1 and that in the F_1 it was 1·52 : 1, *i.e.*, in *ruber* the extent of red colour on the stem was 1·7 times more than that in the F_1. The observations were taken when the plants were one-and-a-half months old. It should be remembered, however, that towards maturity practically the entire stem of both *ruber* and the F_1 becomes red.

IV. EXPERIMENTAL RESULTS

A. Cross No. 1 : H. sabdariffa *var.* albus × altissima *and reciprocal*

Stem colour.—*Albus* has an entirely green stem, while the stem of *altissima* is green with red colour in the leaf-axil and just below the petiole in earlier stages, turning red on maturity of the plant. In F_1 the stem is red from the beginning. In F_2 the following phenotypes and their frequencies were observed :—

	Red (various grades)	Brown	Like *altissima*	Green like *albus*	
Albus × *altissima*	292	40	21	135	=488
Altissima × *albus*	444	125	43	207	=819
Total observed	736	165	64	342	=1307
Total expected on 36 : 9 : 3 : 16 basis	735·12	183·78	61·26	326·72	=1306·88

$\chi^2=2\cdot74$, P between 0·3 and 0·5.

The fit, therefore, is good. The observed frequencies for *albus* × *altissima* deviate significantly from the theoretical frequencies. The discrepancy, however, cannot be accounted for.

It may be pointed out here that the red phenotype showed considerable amount of variation both in the intensity and extent of red colour. The brown phenotype resembled *altissima* except that it had a brownish flush varying both in intensity and extent. The two are practically indistinguishable in advanced stages. 'Brown' will hereafter mean a stem of the above description.

The F_2 results can be explained by making the following assumptions.

R=a factor necessary for the expression of red colour. This is present in *altissima* but absent in *albus*.

X=a factor which produces a red patch in the leaf-axil. This factor is present in both the parents.

A, **B** and **W**=together produce the red patch below the petiole. These are present in both the parents.

M=a factor for the brown stem flush in *albus*.

S=a factor for the scarlet stem flush in *albus*.

On this basis the parental and F_1 genetical formulæ would be as follows :—

Albus =**rrSSMMXXAABBWW**
Altissima =**RRssmmXXAABBWW**
F_1 =**RrSsMmXXAABBWW**

The F_1 is, therefore, heterozygous for **R**, **S**, and **M**, and in F_2 a tri-hybrid segregation of these factors in the presence of **X**, **A**, **B**, and **W*** is expected to give the results shown below :—

$$\underbrace{\overset{\mathbf{RSM}}{27}\quad\overset{\mathbf{RSm}}{9}}_{\substack{36\\ \text{Red of}\\ \text{various}\\ \text{grades}}} \; : \; \underset{\substack{9\\ \text{Brown.}}}{\overset{\mathbf{RsM}}{9}} \; : \; \underset{\substack{3\\ \text{Like}\\ \textit{altissima}}}{\overset{\mathbf{Rsm}}{3}} \; : \; \underbrace{\overset{\mathbf{rSM}}{9}\quad\overset{\mathbf{rSm}}{3}\quad\overset{\mathbf{rsM}}{3}\quad\overset{\mathbf{rsm}}{1}}_{\substack{16\\ \text{Green like } \textit{albus}}}$$

This is realized.

The F_3 results which confirm the above theory are as follows :—

Number and nature of cultures grown in each phenotype	Constitution of F_2 genotype	Breeding behaviour in F_3	Frequencies	
			Observed	Expected
69 cultures with red stem	**RRSSMM** **RRSSMm** **RRSSmm**	Pure Pure Pure	8	7·66
	RRSsMM	3 Red : 1 Brown	1	3·83
	RrSSMM **RrSSMm** **RrSSmm**	3 Red : 1 *albus*	15	15·32
	RRSsMm	12 Red : 3 Brown : 1 *altissima*	4	7·66
	RrSsmm	9 Red : 3 Brown : 4 *albus.*	4	7·66
	RrSsMm	Like F_2	21	15·32
	RRSsmm	3 Red : 1 *altissima*	8	3·83
	RrSsmm	9 Red : 3 *altissima* : 4 *albus*	8	7·66
10 cultures with brown stem	**RRssMM**	Pure	4	1·11
	RRssMm	3 Brown : 1 *altissima*	0	2·22
	RrssMM	3 Brown : 1 *albus*	1	2·22
	RrssMm	9 Brown : 3 *altissima* : 4 *albus*	5	4·44
10 cultures with stem colour like *altissima*	**RRssmm**	Pure	3	3·33
	Rrssmm	3 *altissima* : 1 *albus*	7	6·66
18 cultures with green stem like *albus*	**rrSSMM** **rrSSMm** **rrSsMM** **rrSsMm** **rrSSmm** **rrSsmm** **rrssMM** **rrssMm** **rrssmm**	Pure	18	18

---

*As all the three parents are homozygous for **X**, **A**, **B** and **W**, these factors will not be repeated hereafter for economy of space.

The F_2 results are in fairly close agreement with the theory. The excess in the number of cultures breeding pure for brown stem and the total absence of cultures segregating into 3 Brown : 1 *altissima* might be due to the observations being taken rather late in the season and the probable inclusion of some of the latter type of cultures in the former. The two are almost indistinguishable in advanced stages. A word regarding the red patches on the leaf-veins and petioles may not be out of place here. No plant with any stem colour (patches, brown flush or red flush) was ever observed in F_2 or F_3 without colour in leaf-veins and petioles in this cross, or in cross No. 2. According to Howard and Howard [1924], the factors **X**, **A**, **B**, and **W**, which produce the red markings on the stem (in the leaf-axil and below the petiole) are also responsible for colour in leaf-veins and petiole. Our observations show that the *altissima* contains these factors, and those of Howard and Howard [1924] show that they are present in the other two varieties, *viz.*, *albus* and *ruber*. Thus no segregation of these factors is expected, which is corroborated by our observations.

Nature of F_2 green-stemmed plants.—In order to obtain proof that the extracted green-stemmed progeny in F_2 is not all of the same genetic constitution as *albus*, but is really composed of different kinds of genotypes, eleven green-stemmed F_2 plants were taken at random and crossed with *altissima*. In the next generation these crosses gave four different kinds of progeny, thus proving that the green-stemmed F_2 phenotype is composed of a number of different genotypes.

The four kinds were as follows :—

Behaviour of crosses	*No. of cultures*
1. Pure red	6
2. Red Brown 1 : 1	3
3. Pure Brown	1
4. Red *altissima* 1 : 1	1

The following kinds of progeny which theoretically should have been realized were not observed, most probably because of the small number of green F_2 plants dealt with :—

1. Brown *altissima*
1 : 1
2. Pure *altissima*
3. Red Brown *altissima*
2 : 1 : 1

The back-cross.—The F_1 of *altissima* × *albus* was crossed with *albus* and the following results were obtained :—

	Stem red (of various grades)	Stem green like *albus*	Total
Total observed	50	54	104
Total expected on 1 : 1 basis	52	52	104

$\chi^2 = 0 \cdot 077$

P between 0·8 and 0·7

The fit is good.

Leaf-lobe.—Albus has broad and shallow leaf-lobes and *altissima* narrow and deep leaf-lobes. The F_1 had narrow and deep leaf-lobes, and in F_2 the following phenotypic frequencies were obtained :—

	Narrow leaf-lobed plants like *altissima* and F_1	Broad leaf-lobed plants like *albus*	Total
Albus × *altissima*	366	125	491
Altissima × *albus*	604	214	818
Total observed	970	339	1309
Total expected on 3 : 1 basis .	981·75	327·25	1309

$\chi^2 = 0{\cdot}562$

P between 0·50 and 0·30

The fit is good.

The F_3 results which confirm the above theory are as follows :—

No. and nature of cultures in each phenotype	Constitution of F_2 genotype	Breeding behaviour in F_3	Frequencies	
			Observed	Expected
58 cultures from plants with narrow leaf-lobes	CC Cc	Pure . Like F_2	17 41	19·33 38·66
33 cultures from plants with broad leaf-lobes	cc	Pure	33	33

Back-cross.—The F_1 of *altissima* × *albus* was crossed with *albus* and the following results were obtained :—

(*altissima* × *albus*) × *albus*

(F_1)

	Narrow lobed like *altissima* and F_1	Broad lobed like *albus*	
Total observed . . .	54	49	=103
Total expected on 1 : 1 basis.	51·5	51·5	=103

$\chi^2 = 0{\cdot}121$

P between 0·80 and 0·70

The fit is very good.

Hairiness of stem.—Albus has a smooth stem while the stem of *altissima* is hairy. The F_1 was less hairy than *altissima*. The F_2 progeny consisted of hairy plants of various grades and smooth plants like the non-hairy parent.

As it was found difficult to further classify the hairy progeny into various sub-classes, it was grouped together in one class only. The F_2 frequencies were as follows :—

	Plants with hairy stem	Plants with smooth stem	Total
Albus × *altissima*	333	20	353
Altissima × *albus*	634	39	673
Total observed	967	59	1026
Total expected on 15 : 1 basis .	961·80	64·12	1025·92

$\chi^2 = 0 \cdot 449$

$P = 0 \cdot 5$ approximately

The fit is good.

The above dihybrid segregation could be explained by assuming that **H** and $\mathbf{H_1}$ are two cumulative factors which determine hairiness in stem of *altissima*. When either is heterozygous it is half as effective as when it is homozygous. On these assumptions the genetical constitution of the parents and the F_1 should be as follows :—

Albus — $\mathbf{hhh_1\ h_1}$
Altissima — $\mathbf{HHH_1H_1}$
F_1 — $\mathbf{HhH_1h_1}$

The segregation of both these factors for hairiness should give a 15 hairy (of varying grades) to 1 non-hairy ratio in F_2 as has been realized.

The F_2 results are, therefore, in harmony with the theory. The F_3 results are as follows :—

Number and nature of cultures grown in each phenotype	Constitution of F_2 genotype	Breeding behaviour in F_3	Frequencies	
			Observed	Expected
17 cultures from plants with hairy stem like *altissima*	$\mathbf{HHH_1H_1}$	Pure	17	17
35 cultures from plants with stem intermediate in hairiness (F_1), slightly hairy and very slightly hairy	(1) $\mathbf{HHH_1h_1}$* $\mathbf{HHh_1h_1}$ $\mathbf{hhH_1H_1}$	Different grades of hairiness apparently pure hairy, and pure intermediates	11	15
	(2) $\mathbf{HhH_1h_1}$*	Like F_2	13	16
	(3) $\mathbf{Hhh_1h_1}$*	3 hairy : 1 non-hairy	11	10
4 cultures from plants with smooth stem like *albus*	$\mathbf{hhh_1h_1}$	Pure	4	4

*The other genotypes have not been given for the sake of brevity.

The above results are in agreement with the dihybrid segregation in F_2 and confirm the theory.

Back-cross.—The F_1 of *altissima* × *albus* was crossed back to the recessive parent, *albus*. In the next generation the following results were obtained :—

(*Altissima* × *albus*) F_1	×	*albus*
Intermediate in hairiness		Smooth

	Stem hairy, intermediate and very slightly hairy	Stem smooth	Total
Observed	84	18	102
Expected on 3 : 1 basis . .	76·5	25·5	102

$\chi^2 = 2 \cdot 94$

P between 0·1 and 0·5

The fit is, therefore, fair.

Colour of faded corolla.—The colour of faded corolla in *Hibiscus* is of two types. In some varieties it remains yellow, while in others it turns pinkish. *Albus* has the former type of corolla and the *altissima* the latter type. The F_1 had pink-fading corolla, and in F_2 a ratio of 3 pink-fading corolla to 1 yellow-fading corolla was obtained as shown below :—

	Pink-fading corolla	Yellow-fading corolla	Total
Total observed	845	300	1145
Total expected on 3 : 1 basis .	858·75	286·25	1145

$\chi^2 = 0 \cdot 83$

P between 0·3 and 0·5

The fit, therefore, is good.

It is assumed that **F** is the factor for the production of pink colour in the faded corolla.

This factor is present in *albus* according to the investigations of Howard and Howard [1924], though it cannot find expression because of the absence of **R** in it. *Altissima* must contain both **R** and **F** to give a pink-fading corolla. Both the parents are, therefore, homozygous for **F**, and the production of pink-fading corolla depends upon the presence of **R**. The genetic constitution of parents and F_1 will be as follows :—

Albus . . .	**rrFF** . .	Yellow-fading
Altissima . .	**RRFF** . .	Pink-fading
F_1 . . .	**RrFF** . .	Pink-fading

The segregation of **R** in the presence of **F** should give the following results in F_2 :—

$$\underbrace{\begin{array}{ccc}\mathbf{RRFF} & & \mathbf{RrFF}\\ 1 & : & 2\end{array}}_{\text{3 Pink-fading corolla : 1 yellow-fading corolla}}\begin{array}{cc} & \mathbf{rrFF}\\ : & 1\end{array}$$

This is realized.

It is obvious from this that in this cross, whenever **R** is present, *i.e.*, whenever a plant has any kind of red colour in stem, it will also have a pink-fading corolla. This was actually observed. The frequencies of the phenotypes for this character will, therefore, be the same as those for stem colour if all the coloured classes are put together against the non-coloured class. Therefore, no separate counts were taken for this in F_3.

B. Cross No. 2 : H. sabdariffa *var.* ruber × altissima *and reciprocal*

In this cross excepting stem colour the results for other characters are of the same nature as in cross No. 1, the same factors being involved. Therefore, only the results are presented without repeating the genetical theory for the latter.

Stem colour.—*Ruber* has a red stem and *altissima* has a green stem in early stages with red colour in the leaf-axil and below the petiole. The F_1 had a red stem, practically indistinguishable from *ruber* in intensity. In F_2 the following phenotypes and their frequencies were realized :—

	Red (various grades)	Brown	*Altissima*	Total
Ruber × *altissima*	289	91	17	397
Altissima × *ruber*	589	142	52	783
Total observed	878	233	69	1180
Total expected on 12 : 3 : 1 basis . .	885·00	221·26	73·75	1180

$\chi^2 = 0{\cdot}985$,

P between 0·5 and 0·7

The fit, therefore, is good.

Variation, both in intensity and extent of colour, existed in the red phenotype, but it was less than in cross No. 1. The brown flush in the phenotype 'Brown' was slightly deeper in colour in this cross than in cross No. 1.

The theory for the stem colour inheritance in this cross is the same as that proposed for stem colour in cross No. 1. *Ruber* possesses all the factors present in *albus* and **R** in addition.

The genetic formulæ for the parents and the F_1 should, therefore, be as follows :—

Ruber —**RRSSMM**
Altissima —**RRssmm**
F_1 —**RRSsMm**

The F_1 is, therefore, heterozygous for **S** and **M**. The segregation of these two factors should give the following results in F_2 :—

$$\underbrace{\begin{array}{cc}\mathbf{RSM} & \mathbf{RSm}\\ 9 & 3\end{array}}_{\substack{12\\ \text{Red of various grades}}} \quad : \quad \begin{array}{c}\mathbf{RsM}\\ 3\\ 3\\ \text{Brown}\end{array} \quad : \quad \begin{array}{c}\mathbf{Rsm}\\ 1\\ 1\\ \textit{Altissima}\end{array}$$

This result is realized.

For the F_3 study of the red phenotype, we selected twelve plants from amongst those which had distinctly very deep red stem, and thirty-four plants were taken at random from those plants which were less intense in colour. All the former bred true while the latter segregated in four different ways. The complete F_3 results are as follows :—

Number and nature of cultures grown in each phenotype	Constitution of F_2 genotype	Breeding behaviour in F_3	Frequencies	
			Observed	Expected
12 cultures from plants with very deep red stem	**RRSSMM**	Pure	12	12
36 cultures from plants with red stem	**RRSSMm**	Apparently pure red but actually segregating into very deep red and red plants	..	9·82
	RRSsMM	3 Red : 1 Brown	11	6·55
	RRSsMm	Like F_2	9	13·10
	RRSsmm	3 Red : 1 *altissima*	7	6·55
13 cultures from plants with brown stem	**RRssMM**	Pure	2	4·33
	RRssMm	3 Brown : 1 *altissima*	11	8·66
15 cultures from plants with stem like *altissima*	**RRssmm**	Pure	15	15

The above results agree fairly closely with the theory.

Leaf-lobe.—Ruber, like *albus*, has a broad leaf-lobe while the leaf-lobe of *altissima* is narrow. The F_1 had a narrow leaf-lobe, and in F_2 a ratio of 3 narrow leaf-lobed plants : 1 broad leaf-lobed plant was obtained as shown below :—

	Narrow-lobed plants (like *altissima* and F_1)	Broad-lobed plants (like *ruber*)	Total
Ruber × *altissima*	441	131	572
Altissima × *ruber*	442	150	592
Total observed	883	281	1164
Total expected on 3 : 1 basis .	873	291	1164

$$\chi^2 = 0{\cdot}458$$

P between 0·5 and 0·7

The fit is good.

The F_3 results which confirm the theory are given below :—

Number and nature of cultures grown in each phenotype	Constitution of F_2 genotype	Breeding behaviour in F_3	Frequencies	
			Observed	Expected
53 cultures from plants with narrow lobes	CC Cc	Pure Like F_2	14 39	17·66 35·32
23 cultures from plants with broad lobes	cc	Pure	23	23

The F_3 confirms the monohybrid segregation in F_2.

Hairiness.—Ruber is non-hairy and *altissima* is hairy. The F_1 was hairy but less hairy than *altissima*. The following results were obtained in F_2 :—

	Stem hairy (various grades)	Stem smooth	Total
Altissima × *ruber*—			
Total observed	472	51	523
Total expected on 15 : 1 basis .	490·5	32·7	523·2

$\chi^2 = 11 \cdot 16$

P less than 0·01

The fit is bad.

The F_2 of *ruber* × *altissima* was repeated the following year and the results given below were obtained :—

	Stem hairy (various grades)	Stem smooth	Total
Total observed	73	3	76
Total expected on 15 : 1 basis .	71·25	4·75	76

$\chi^2 = 0 \cdot 69$

P between 0·5 and 0·3.

The fit is good.

F_3 results are as follows :—

Number and nature of cultures grown in each phenotype	Constitution of F_2 genotype	Breeding behaviour in F_3	Frequencies	
			Observed	Expected
10 cultures from plants hairy like *altissima*	$\mathbf{HHH_1H_1}$	Pure	10	10
39 cultures from plants slightly hairy, intermediate in hairiness like F_1 and very slightly hairy	(1) $\mathbf{HHH_1h_1}$* $\mathbf{HHh_1h_1}$ $\mathbf{hhH_1H_1}$	Segregating into different grades of hairiness and practically pure for intermediate hairiness	15	16·71
	(2) $\mathbf{HhH_1h_1}$*	Like F_2	17	11·14
	(3) $\mathbf{Hhh_1h_1}$*	3 hairy : 1 smooth	7	11·14
2 cultures from plants smooth like *ruber*	$\mathbf{hhh_1h_1}$	Pure	2	2

*The other genotypes have not been given for the sake of brevity.

The F_3 results are in harmony with the F_2 results and the theory.

V. SUMMARY

1. The stem colour in *Hibiscus* may be in the form of (1) red patches, as in *altissima*, or in the form of (2) light brown flushes or washes as those in the brown phenotype realized in the F_2's of the two crosses, or (3) as deep flushes or washes as present in *ruber*.

No. (1) is due to a set of factors, **X**, **A**, **B**, and **W**, which is present in all the three varieties used as parents.

No. (2) is due to a factor, **M**, present in *albus* and *ruber* and absent in *altissima*.

No. (3) is due to a factor, **S**, present both in *albus* and *ruber* and absent in *altissima*.

2. The expression of any colour depends upon another factor **R**, which is present in *ruber* and *altissima* and absent in *albus*, for which reason it (*albus*) appears green even though it possesses the full quota of colour factors.

3. The difference between *albus* and *altissima* being of three factors, *viz.*, **R**, **S**, and **M**, a tri-hybrid F_2 segregation (36 Red : 9 Brown : 3 *altissima* : 16 *albus*) for stem colour is obtained. This is supported by the F_3 and back-cross results.

4. The extracted green-stemmed recessives like *albus* in F_2 of the cross, *albus* × *altissima*, have been proved to be of different genetic constitution.

5. *Ruber* and *altissima* differ in two factors, *viz.*, **S** and **M** for stem colour, and a dihybrid F_2 segregation (12 Red : 3 Brown : 1 *altissima*) is realized and this result is supported by the F_3 observations.

6. The pink colour of the faded corolla depends upon a factor **F**, which is present in all the parents. It cannot find expression in the absence of **R**. Thus in the cross, *albus* × *altissima*, with the segregation of **R** a ratio of 3 pink-fading corolla : 1 yellow-fading corolla is obtained.

7. Narrow leaf-lobe is found to be dominant to broad leaf-lobe on a 3 : 1 basis. This is confirmed both by the F_3 and back-cross data.

8. Hairiness of stem depends upon two factors, cumulative in effect, giving an intermediate F_1 and a ratio of 15 hairy (various grades) : 1 non-hairy in F_2.

The results are supported by F_3 and back-cross results.

9. A closer affinity between *altissima* and *H. sabdariffa* than between the former and *H. cannabinus* is indicated by the results of crossings.

REFERENCES

Howard, A. and Howard, G. L. C. (1911). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **4**, No. 2, 1-36

——————————— (1924). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **13**, No. 3, 47-85

Khan, A. R. (1930). *Agric. J. Ind.* **25**, 210-212

Kottur, G. L. (1919). *Agric. J. Ind.* **14**, 177-179

STUDIES IN VERNALISATION OF MUSTARD

(A PRELIMINARY REPORT)

BY
B. SEN
AND
S. C. CHAKRAVARTI
Vivekananda Laboratory, 8 Bosepara Lane, Calcutta

(Received for publication on 8th February 1938)

(With Plate X)

PRE-SOWING treatment of germinating seeds of annual cereals by which desirable changes are induced in the natural habits of the plants grown from these seeds is now generally known as vernalisation. Its practical utilities, mostly exploited by U.S.S.R. agronomists, lie in : (*i*) producing earlier crop ; (*ii*) growing plants in regions where they do not naturally reproduce, and (*iii*) accelerating the work of plant breeders.

The growth of plants, which is increase in bulk, and stages of development processes leading to reproduction (seeding) are not identical phenomena. Developmental processes are completed in a series of stages involving qualitative changes. The most important of these are the 'thermo-stage' and the 'photo-stage'. According to the species and strain each cereal plant requires definite intensity and duration of temperature and light for the induction of the specific qualitative changes needed for completion of the reproductive development. Lacking these temperature and light conditions vegetative growth may continue without flowering and seeding.

The technique of vernalisation rests on the fundamental fact that as soon as growth is initiated in the embryo of a dormant seed, it ceases to be a seed and becomes a growing plant in all practical physiological sense. It has been experimentally observed that the necessary qualitative changes for thermo- and photo-stages could be induced in the germinating seeds, as effectively as in growing plants, by subjecting the seeds to the required doses of temperature and light. This pre-sowing treatment of the germinating seeds makes the plants grown from these seeds independent of the subsequent lack of appropriate temperature and light factors of the environment needed for initiation of the reproductive cycle of development. Thus winter wheat sown in late spring will not seed the same year, but pre-sowing treatment of germinated seeds to definite periods of low temperature will make winter wheat sown in late spring fruit the same year.

The Bulletin of the Imperial Bureau of Plant Genetics on "Vernalization and Phasic Development of Plants" [1935] summarises the theory and techniques of vernalisation and the results of experimental observations carried out in different parts of the world, up to December 1935. Regarding the work done in India the Bulletin notes, "In a general review published in the *Madras Agricultural Journal*, 1935, it is stated that the results in India have not so far been promising." (p. 133). The following is a preliminary report of our vernalisation experiments on mustard carried out from July to December, 1937, in Almora, U. P., to find out: (*i*) whether mustard could be vernalised at all, (*ii*) if mustard seeds could be vernalised, to observe the effects of duration of pre-sowing low-temperature treatment, and (*iii*) to find out if and how the technical practical difficulties involved in using vernalised mustard seeds for agricultural purposes could be overcome.

MATERIAL AND METHODS

The mustard seeds used in these experiments were pure strain of *Brassica juncea* Hooker, Type 27, supplied by the Director of the Imperial Agricultural Research Institute, New Delhi. The seeds were subjected to chilling at two different stages of germination, *viz.*—(A) seeds just sprouted, and (B) unsplit seeds previously soaked under water for twenty-four hours. For convenience these will subsequently be referred to as sprouted and unsplit vernalised seeds respectively.

Vernalised seeds, along with control in the same stage of growth, were sown in alternate garden plots and in pots containing thoroughly mixed and sieved soil. Each pot was divided into four sectors and two each of control and vernalised seeds were sown in alternate sectors. After good vegetative growth had started, pots were thinned to four similarly growing plants, two of control and two of vernalised seeds.

The effectiveness of vernalisation treatment of seeds was judged mostly by observing the earliness in the number of days of first opening of flowers in plants from vernalised seeds, as compared to the control. Available data of the shortening in the total period of duration of flowering and in the maturing of the crop in plants from vernalised seeds were also collected.

From preliminary experiments it was found that the mustard seeds used in these experiments absorbed in course of five hours nearly seventy-five per cent of the total water they could absorb in twenty-four hours' soaking. For vernalising sprouted seeds, the seeds used for chilling were first soaked in excess of water for four to five hours and were afterwards spread over a glass plate (6 in. × 8 in.) covered with four layers of absorbent gauze (8 in. × 10 in.). The plate was transferred to a moist chamber, which consisted of a tin box paraffined inside and containing a little water and a loose-fitting cover. An empty biscuit tin is a convenient box for this purpose. The glass plate was placed on three blocks of paraffin or inverted small Petri dishes, with the ends of the gauze dipping into the water at the bottom of the box. This arrangement, as compared with others previously tried by us, was found to be very suitable for ensuring adequate supply of moisture to the seeds, alike for the period of germination and subsequent chilling. As previously observed by Lojkin [1936], it was found that too much of water interferes with the process of germination, and too little, with the process of development.

The seeds were first allowed to germinate in the moist chamber under laboratory conditions. After about ninety per cent of the seeds had sprouted, which generally took from twenty-four to thirty hours, the moist chamber containing the seeds was transferred to a kerosine-operated electrolux for chilling.

Daily readings of the maximum-minimum thermometer placed inside the moist chamber were taken. It must be noted, however, that from these readings no precise idea could be obtained as to the duration of these temperature ranges. Particularly is this true of the maximum recorded by the thermometer. For during the interval of cleaning and refuelling of the electrolux, which generally takes only half an hour, the temperature shoots up.

EXPERIMENTS

(*A*) *Sprouted vernalised seeds*

The sprouted mustard seeds were chilled for twelve days at 2-7°C. and the control seeds, germinated to the same stage of growth-lengths. Both were sown alternately in eight small plots in the garden on July 19. On account of the damage done to the seedlings by the monsoon conditions, and the consequent poor growth of the surviving plants, the experiment was practically abandoned, but the conspicuous flowering of the plants from the vernalised seeds drew our attention on August 23. The first flowering thus came after thirty-five days of planting. The first flowering in plants from control seeds appeared after fifty-five days ; thus an earliness of twenty days in plants from vernalised seeds was observed, and irrespective of the nature of the vegetative growth of the plants. Furthermore, the crop of the vernalised seeds was ready for harvesting ninety-one days after planting, while that of the control seeds was ready after 131 days, showing a difference of forty days.

Another batch of seeds was vernalised for nine days at 2-7°C. and sown in four pots on July 30. In this case an earliness of thirteen days in the first opening of the flowers was observed in the plants from vernalised seeds as compared to the control. The period of flowering and the maturity of the crop could not, however, be observed, as small caterpillars practically destroyed the plants.

These two preliminary experiments encouraged us to undertake further experiments, both in pots and in small garden plots, to find out the effect of increased dose of chilling. For each dose of chilling four pots were used. In

Table I are summarised the results so far obtained with pot plants. About 1,000 sprouted seeds were chilled with the idea of taking samples for planting after different periods of chilling. After four days' chilling at 2-9°C. (No. 1, Table I) the electrolux suddenly went out of order and the seeds had to be discarded. The observations Nos. 2, 3 and 4 in Table I are from the same batch of sprouted seeds, subsequently chilled, taken out of the electrolux at intervals of seven, ten and thirteen days of chilling, in this case at 0-5°C. It will be seen that with increased number of days of chilling greater earliness in first opening of flowers of the plants from vernalised seeds was induced. Observation No. 1 shows that even four days of chilling is effecting an earliness in the opening of the first flowers by nine days, and again of eighteen days in the completion of the flowering period. In Plate X, photographs of the four pots used in observation No. 1, Table I, show the difference in the development processes of the plants from the vernalised and control seeds. Plants from control seeds are still in the vegetative stage of growth, while plants from vernalised seeds are flowering.

Table I

Effect of vernalisation of sprouted mustard seeds (*grown in pots*)

No.	Date of sowing	Days of chilling	Temp. (°C.)	Earliness in first flowering (days)	Earliness in completion of flowering (days)
1	Sept. 2	4 days	2—7	9	18
2	„ 12	7 „	0—5	7	32
3	„ 15	10 „	0—5	12	31
4	„ 18	13 „	0—5	15	*

* Flowering of the control not finished by December 20th, when the Laboratory was moved to Calcutta.

The observations on sprouted vernalised seeds grown in small garden plots are summarised in Table II. It will be seen that with increased period of chilling greater earliness in opening of the first flowers of the plants from vernalised seeds has been induced. The period of flowering of the controls was not finished, and these data could not be recorded. Nine days' chilling at 0-5°C. produced an earliness of 12·4 days, 12 days' chilling, 13·9 days and 15 days' chilling, 23·1 days.

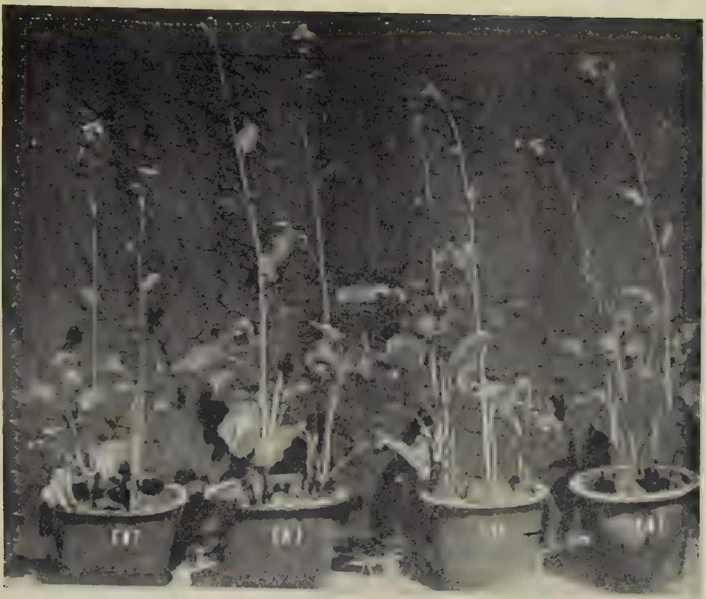


Fig. A. Mustard plants grown from control and vernalised seeds (Note that two plants from control seeds in each of the four pots are still in vegetative stage, while those from vernalised seeds, two in each pot, are flowering)

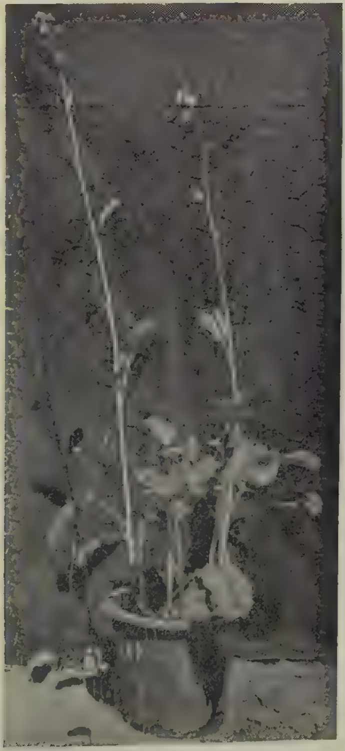


Fig. B. Enlarged photo of pot No. 2

TABLE II

Effect of vernalisation of sprouted mustard seeds in inducing earliness of first flowering. (C), plants from control, (V), from vernalised seeds (grown in garden plots)

No.	Number of plants		Date of sowing	Days of chilling	Temp. (°C.)	Mean period per plant with S. E.	
	(C)	(V)				(C)	(V)
1	61	32	Oct. 1	9	0—5	82·2±1·31	69·8±1·99
2	11	13	„ 4	12	0—5	70·6±2·64	56·7±2·57
3	31	44	„ 7	15	0—5	77·5±2·43	54·4±1·41

The experiments just described show definitely that germinated mustard seeds subjected to pre-sowing chilling produce plants which flower and fruit earlier than the control sown under similar conditions, and that with increasing dose of chilling (the limit not yet determined) greater earliness is induced. But it was also found that percentage germination of sprouted vernalised seeds was reduced by thirty to forty per cent compared with the control, and this under very careful handling of the vernalised seeds. To avoid mechanical injury during sowing, in our experiments, camel's-hair brushes were used. It was found that, to obtain any appreciable germination, sprouted vernalised seeds must be planted soon after removal of the seeds from the electrolux. Drying of the sprouted vernalised seeds was found to be fatal. Since the cultivators cannot be expected individually to possess an electrolux, and neither can the laboratory experimental method of careful sowing of individual seeds be used for field sowing of mustard, experiments were next carried out to find out whether mustard seeds could be vernalised under conditions suitable for the Indian cultivators to handle for field sowing.

(*B*) *Unsplit vernalised seeds*

It was found that mustard seeds placed under water for forty-eight hours or more would not sprout, yet the subsequent germinating capacity remained undamaged. Seeds soaked under water for twenty-four hours were spread over gauze in the moist chamber and placed immediately in the electrolux, where they were chilled for different periods.

Only one pot experiment with unsplit vernalised seeds was carried out. Unsplit seeds were chilled for thirteen days at 0-5°C. During the period of chilling the seed-coats did not burst. The control along with vernalised seeds were planted in four pots. The earliness of first opening of flowers in the plants from unsplit seeds chilled for thirteen days was found to be ten days.

The observations on unsplit vernalised mustard seeds grown in small garden plots are summarised in Table III. It will be seen that unsplit mustard seeds previously soaked under water for twenty-four hours can be vernalised. Lysenko's original theory that " the process conditioning the sexual reproduction of cereals may occur not only in growing plants, but also in a seed with an embryo which has just commenced development, but not broken the seed-coat " is also thus applicable to mustard seeds. It will also be noticed that the degree of vernalisation induced in unsplit mustard seeds increases with period of chilling. In this case, as also with sprouted seeds, the maximum effective period of chilling could not be observed. The Almora Laboratory had to be closed in December and to allow time for observations our last sowing had to be made in early October.

TABLE III

Effect of vernalisation of unsplit mustard seeds in inducing earliness of first flowering; (C), plants from control, (V) from vernalised seeds (grown in garden plots)

No.	Number of plants		Date of sowing	Days of chilling	Temp. (°C.)	Mean period per plant with S. E.	
	(C)	(V)				(C)	(V)
1	61	51	Oct. 1	9	0—5	82·2±1·31	76·5±1·25
2	31	58	„ 7	13	0—5	77·5±2·43	68·1±0·71
3	31	50	„ 7	15	0—5	77·5±2·43	67·4±1·23

To determine the germinating capacity of the unsplit vernalised seeds they were sown in small plots in the garden. Table IV, which summarises the observations, shows that the germinating capacity of unsplit vernalised seeds remains unimpaired. Unsplit vernalised seeds from Almora sown in Calcutta after being dried for 105 days showed similar germinating capacity as the control.

TABLE IV

Germinating capacity of unsplit vernalised mustard; (C), control and (V), unsplit vernalised seeds (sown in garden plots)

Date of sowing	Number of seeds		Period of chilling of	Germination percentage	
	(C)	(V)	(V)	(C)	(V)
Sept. 21	160	160	13 days at 0—5°C.	79·3	78·75
Oct. 1	100	100	9 „ „ 0—5°C.	80	75
„ 21	200	200	25 „ „ 0—5°C.	74	78

DISCUSSION AND CONCLUSIONS

In the observations recorded above only the thermo-stage of vernalisation has been studied. The day-lengths in which plants are grown have an effect on the initiation of the reproductive cycle, photo-stage of vernalisation. A criticial discussion on photo-stage of vernalisation will be found in the recent paper of Purvis and Gregory [1937]. Therefore the observations on earliness of opening of flowers in plants from vernalised seeds subjected to similar doses of chilling and planted on the same date only are comparable. Sowings of October 1 and 7 of seeds subjected to nine and fifteen days' chilling (Tables II and III) show that the degree of vernalisation induced is much greater in sprouted than in unsplit seeds. Thus for the same dose of chilling an earliness of 12·4 and 23·1 days in sprouted, and only 5·7 and 10·1 in days in corresponding unsplit vernalised seeds planted on same dates were observed. This is in agreement with observations on winter wheat by Lojkin [1936], that greater degree of vernalisation is produced in plants which actively germinate during the low-temperature treatment. Against this one advantage of sprouted vernalised seeds, unsplit vernalised seeds offer several, and these are of more significant nature for purposes of practical agriculture, *viz.* : (*a*) unsplit vernalised seeds can be easily transported and handled without injury to the seeds ; (*b*) the per cent germination of unsplit vernalised seeds as compared to the control is practically the same, while per cent diminution of germination in sprouted vernalised seeds varies from thirty to forty per cent ; (*c*) sprouted vernalised seeds have to be sown with great care and soon after removal from the electrolux, for drying is fatal for these seeds, while unsplit vernalised seeds can be dried, and drying does not affect their subsequent germinating capacity.

On account of the preliminary nature of these experiments for garden sowing only two replications were generally planned. For our studies this summer adequate experiments have been designed by Mr. S. S. Bose of the Statistical Laboratory, Calcutta, to determine the maximum degree of vernalisation that can be induced in unsplit mustard seeds and also the number of days unsplit vernalised seeds will retain the effect of vernalisation when dried.

SUMMARY

Experiments with mustard (*Brassica juncea* Hooker, Type 27) were undertaken to find out whether mustard seeds could be effectively vernalised and this with a view to their possible agricultural use.

Seeds in two different stages of germination, *viz.* (A), seeds just sprouted and (B), seeds with unsplit seed-coats previously soaked under water for twenty-four hours, were subjected to different periods of low temperature.

Results so far observed from July to October, 1937, sowings alike in pots and in small garden plots, clearly indicate that :—

(*i*) Plants from both (A) and (B) types of vernalised seeds show definite earliness in the opening of first flowers as compared to the plants from control seeds grown under similar conditions.

(*ii*) For the same dose of chilling the degree of vernalisation induced in sprouted seeds is much greater than that induced in unsplit seeds.

(*iii*) Against this one advantage of the sprouted vernalised seeds, unsplit vernalised seeds offer several and these are of more significant nature for purposes of practical agriculture.

Experiments are planned for this summer (1938) to find out the maximum degree of vernalisation that can be induced in unsplit seeds by increasing the dose of chilling and also to determine the number of days unsplit vernalised seeds can retain the effects of vernalisation when dried.

The expenses of this investigation have been met by grants to this Laboratory from The Elmgrant Trust of Dartington Hall, Totnes and the Imperial Council of Agricultural Research, New Delhi.

REFERENCES

Imperial Bureaux of Plant Genetics (1935). 'Vernalization and Phasic Development of Plants', *Bull. No.* **17**

Lojkin, M. (1936). *Cont. Boyce Thompson Institute* **8,** 237-261

Purvis, O. N. and Gregory, F. G. (1937). *Ann. Bot.* (*New Series*) **1,** 569-591

PRELIMINARY STUDIES IN THE RESPIRATION OF SUGARCANE *IN SITU*

BY

K. L. KHANNA

AND

P. C. RAHEJA

Sugarcane Research Scheme, Bihar

(Received for publication on 16th December 1937)

(With five text-figures)

I. INTRODUCTION

SUGARCANE planting season in Bihar extends from the beginning of February to the middle of March. Soon after germination the crop is subjected to an increasing stress of hot weather—particularly so in the rain-fed tract north of the Ganges—so that conditions conducive to favourable growth in the early part of its life are lacking. Varieties show considerable variation in their passage through dry weather. Some maintain a fairly high level of daily growth without an evident check, while others are affected to a more or less extent. This susceptibility to drought in the latter case is brought about by a sum-total of setbacks in the various processes concerned with growth and one of these processes is the respiratory function.

Respiration studies have chiefly been carried out in the laboratory by various workers such as Blackman and his colleagues [1928], who have studied the relationship of different factors on the course of changes in the intensity and rate of respiration. The results obtained with individual factors in the laboratory, however, do not convey proper understanding of the physiological behaviour of plants under field conditions for the simple reason that the interaction in the inner life processes of a plant is very much complicated by the external factors, the action of any one of which is in itself markedly influenced by the presence of other factors. It, therefore, becomes difficult to appraise the limiting effect of any one external factor on the physiological processes as related to growth of crops.

Experiments herein described were, therefore, undertaken to follow the course of respiratory activity *in situ* through the hot weather, with a view to study the effect of increasing drought and the response to it shown by different varieties of cane.

II. Apparatus and methods

The apparatus (Fig. 1) was a modification of the one used by Luthra and Cheema [1931]. An aspirator was employed in place of the suction pump and the mercury regulator. The rate of flow was regulated approximately to one bubble per second by means of a screw-clamp attached to the rubber tubing outlet. As the suction force of the aspirator was small, a set of U-tubes each containing 5-10 c.c. of 1·5 normal sodium hydroxide solution was used for absorption of carbon dioxide. Prior to its entering the respiration chamber, air was freed of carbon dioxide by passing it through bottles containing normal sodium hydroxide solution. This air was then passed through a U-tube containing baryta water to test whether it was free of carbon dioxide. Freedom from moisture was ensured by passing the air through a bottle containing pumice stones saturated with concentrated sulphuric acid. The estimations were made by the continuous current method of gaseous exchange and the method of double titration for determining carbon dioxide was used throughout. From the carbon dioxide evolved rates of respiration were calculated on the basis of fresh weight of the material.

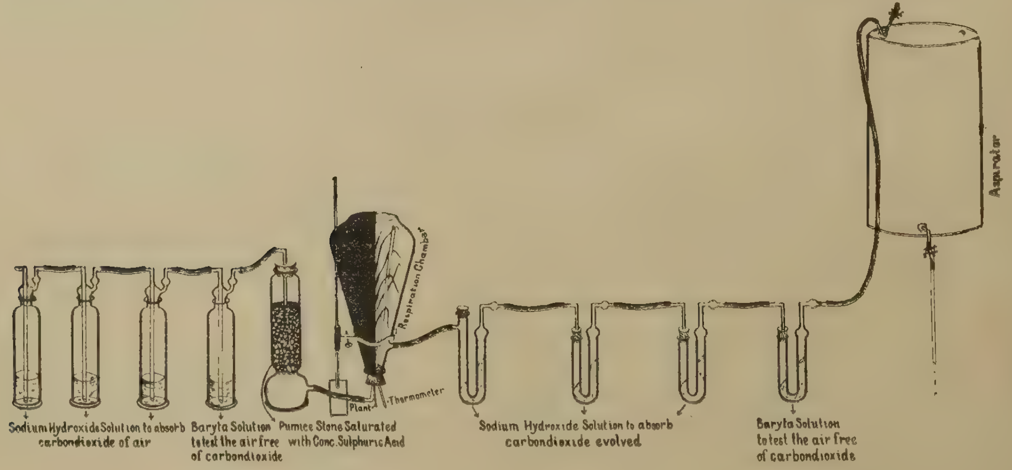

Aspirator
Respiration Chamber
Plant
Thermometer
Sodium Hydroxide Solution to absorb carbondioxide of air
Baryta Solution to test the air free of carbondioxide
Pumice Stone Saturated with Conc. Sulphuric Acid
Sodium Hydroxide Solution to absorb carbondioxide evolved
Baryta Solution to test the air free of carbondioxide

Fig. 1. Respiration apparatus

Eight sugarcane varieties that comprised early, mid-season and late maturing types and whose performance as to their passage through hot weather and their ability to withstand drought was well known (Table I) were selected for the purpose of this study.

TABLE I

Characteristics of varieties under study

Serial No.	Name of variety	Period of ripening : early, mid-season or late	Susceptibility to drought : high, medium or low
1	Co 214	Early . . .	Medium
2	Co 299	Early . . .	Medium
3	Co 313	Medium early . .	Medium low
4	Co 210	Mid-season . .	Medium
5	Co 213	Mid-season . .	High
6	Co 356	Mid-season . .	High
7	Co 326	Late . . .	Low
8	Co 331	Late . . .	Low

Normal representative plants in each of these varieties were selected before starting the experiment. In each variety one representative plant was taken on any one day during each of the four periods and two-hourly readings for respiration were worked out through the day. Temperature records both at the start and close of each set of two-hourly period were maintained. The whole tuft of foliage above the last leaf showing transverse mark was enclosed in the respiration chamber, which was painted black and was further covered over with a thick black cloth to eliminate photo-synthetic activity. At the conclusion of each set of experiments the enclosed tier of leaves was severed off the plant and weighed in the laboratory close by. The probable course of metabolism exhibited by varieties was then determined from the carbon dioxide output on a unit fresh weight in single representative plants in each case and in all four such determinations were made during the dry weather.

III. EXPERIMENTAL RESULTS

1. The results (Figs. 2, 3 ; Tables II-V) indicate that assuming the rate of respiration to be constant between the hours of 7-30 A.M. to 9-30 A.M. each of the varieties shows a subsequent rise in the respiration rate in the next two hours followed by a fair fall between the hours of 11-30 A.M. to 2-0 P.M., after which the plant tends to regain its normal rate of activity provided the temperatures do not remain very high. This course of variations has been exhibited by all the varieties in the three groups taken up.

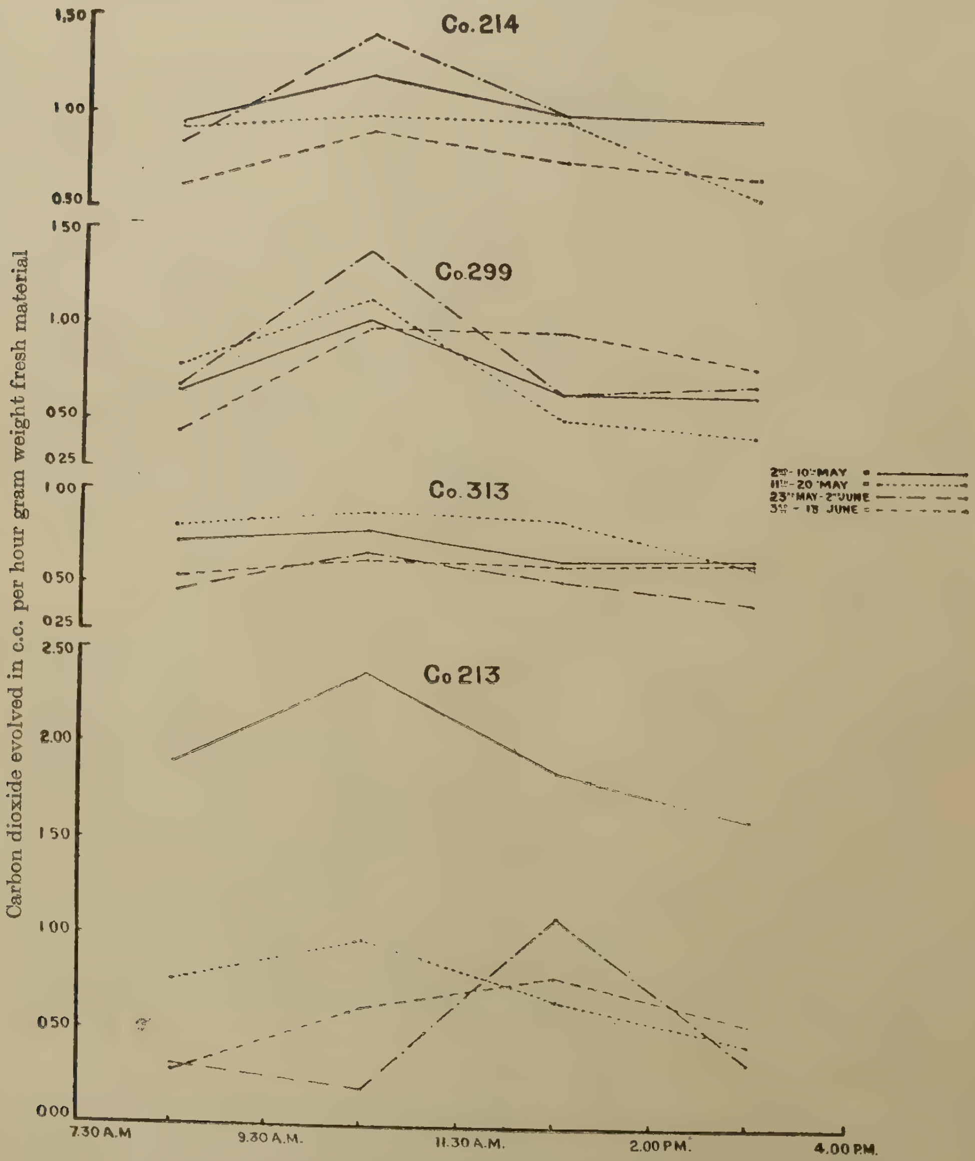


FIG. 2. Two-hourly fluctuations in respiration during advancing hot weather

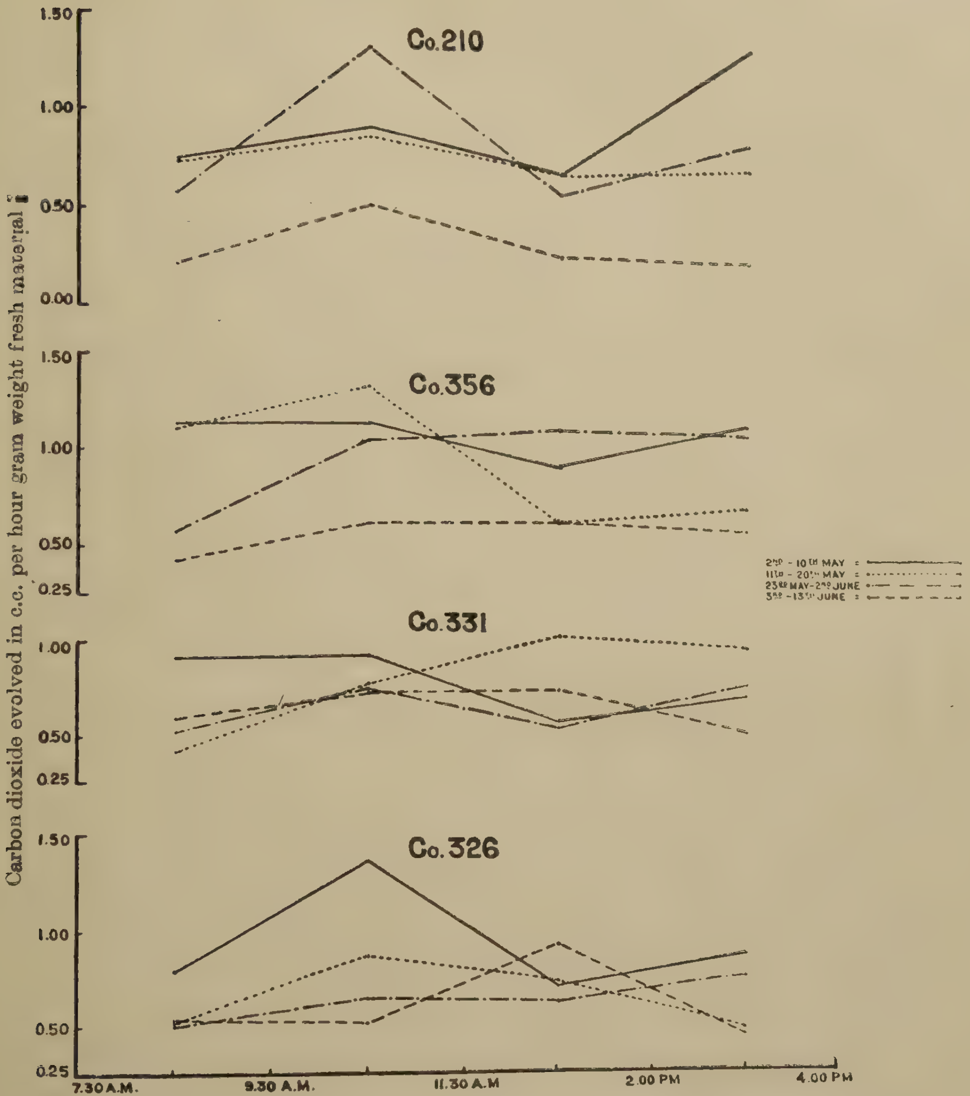


Fig. 3. Two-hourly fluctuations in respiration during advancing hot weather

TABLE II

Metabolic activity in situ *(2nd May to 10th May)*

Time	Early varieties						Mid-season varieties						Late varieties			
	Co 214		Co 299		Co 313		Co 213		Co 210		Co 356		Co 331		Co 326	
	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.
7-30 A.M.	80		82		84		82		83		82		84		84	
to		0·94		0·65		0·72		1·9		0·76		1·13		0·91		0·78
9-30 A.M.	100		88		96		90		88		91		90		96	
9-30 A.M.	100		88		96		90		88		91		91		96	
to		1·19		1·01		0·79		2·41		0·91		1·14		0·94		1·38
11-30 A.M.	104		97		102		100		100		99		101		102	
11-30 A.M.	104		97		102		101		100		99		101		102	
to		0·98		0·64		0·63		1·86		0·68		0·90		0·59		0·70
2-0 P.M.	106		105		105		106		103		105		104		106	
2-0 P.M.	106		105		105		106		103		104		104		106	
to		0·98		0·62		0·65		1·62		1·31		1·12		0·71		0·87
4-0 P.M.	100		100		101		102		94		96		98		100	

TABLE III

Metabolic activity in situ (*11th May to 20th May*)

Time	Early varieties						Mid-season varieties						Late varieties			
	Co 214		Co 299		Co 313		Co 213		Co 210		Co 356		Co 331		Co 326	
	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.
7-30 A.M. . .	90		84		83		92		84		84		80		86	
to		0·93		0·78		0·80		0·75		0·74		1·11		0·44		0·52
9-30 A.M. . .	98		100		90		96		96		100		87		94	
9-30 A.M. . .	98		100		90		97		96		100		87		94	
to		0·99		1·11		0·87		0·98		0·86		1·33		0·78		0·87
11-30 A.M. .	104		104		102		104		102		104		98		102	
11-30 A.M. .	104		104		102		104		102		104		98		102	
to		0·95		0·50		0·84		0·66		0·69		0·62		1·03		0·73
2-0 P.M. . .	108		108		106		108		105		106		102		106	
2-0 P.M. . .	108		107		106		108		104		106		102		106	
to		0·58		0·41		0·61		0·48		0·70		0·70		0·97		0·49
4-0 P.M. . .	104		102		102		102		98		100		102		102	

TABLE IV

Metabolic activity in situ *(23rd May to 2nd June)*

Time	Early varieties						Mid-season varieties						Late varieties			
	Co 214		Co 299		Co 313		Co 213		Co 210		Co 356		Co 331		Co 326	
	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in °F.	Respiration rate in c.c.
7-30 A.M.	86		0		88		84		92		90		86		85	
to		0·84		0·67		0·46		0·31		0·64		0·60		0·53		0·51
9-30 A.M.	98		93		98		92		98		96		95		92	
9-30 A.M.	98		93		98		92		98		96		96		92	
to		1·40		1·37		0·66		0·20		1·53		1·05		0·77		0·65
11-30 A.M.	106		104		106		100		103		101		103		99	
11-30 A.M.	106		104		106		100		103		101		103		100	
to		0·98		0·64		0·54		1·10		0·57		1·10		0·55		0·63
2-0 P.M.	110		109		110		105		110		102		108		106	
2-0 P.M.	Spoiled		109		110		105		110		102		107		106	
to				0·69		0·43		0·36		0·83		1·09		0·78		0·75
4-0 P.M.			102		105		103		101		100		101		102	

TABLE V

Metabolic activity in situ (*3rd June to 13th June*)

Time	Early varieties						Mid-season varieties						Late varieties			
	Co 214		Co 299		Co 313		Co 213		Co 210		Co 356		Co 331		Co 326	
	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.	Temperature in ° F.	Respiration rate in c.c.
7-30 A.M.	90		85		88		78		80		80		90		84	
to		0·61		0·44		0·54		0·29		0·21		0·43		0·60		0·53
9-30 A.M.	98		91		92		88		92		92		96		88	
9-30 A.M.	98		91		92		88		92		92		96		88	
to		0·90		0·97		0·64		0·61		0·51		0·62		0·74		0·51
11-30 A.M.	102		99		100		98		99		98		100		93	
11-30 A.M.	102		99		100		98		99		98		100		93	
to		0·75		0·96		0·61		0·79		0·26		0·62		0·75		0·93
2-0 P.M.	105		106		105		107		105		106		104		106	
2-0 P.M.	105		106		105		106		105		106		105		106	
to		0·69		0·76		0·62		0·51		0·22		0·58		0·52		0·45
4-0 P.M.	100		102		99		102		102		100		102		101	

2. Considering the varietal behaviour in respect of the two-hourly fluctuations in the respiratory activity, it is observed that some varieties are more consistent and less fluctuating than the others (Figs. 2, 3). Of the varieties studied, Co 213 is found to be most susceptible while Co 313 is least affected. The other varieties range themselves between these two extremes in the following ascending order namely, Co 299, Co 210, Co 356, Co 326, Co 331 and Co 214.

3. The collective behaviour of varieties in relation to the two-hourly fluctuations in the respiration rate during the day (Fig. 4, Table VI) is comparatively more consistent in the first (2nd to 10th May) and the second (11th to 20th May) series than it is in the third one (23rd May to 2nd June) where it gets very much disturbed. In the fourth series (3rd to 13th June) again it is more or less regular and tame. A probable explanation for this physiological activity of the plant has been offered later in the text.

Table VI

Periodic variations in the respiratory activity of different varieties (c.c. of carbon dioxide evolved)

Period	7-30 to 9-30 A.M.	9-30 to 11-30 A.M.	11-30 A.M. to 2-0 P.M.	2-0 to 4-0 P.M.
I. Early group				
1. Co 214				
1st series	0·94	1·19	0·98	0·98
2nd series	0·93	0·99	0·95	0·58
3rd series	0·84	1·40	0·98	..
4th series	0·61	0·90	0·75	0·69
2. Co 299				
1st series	0·65	1·01	0·64	0·62
2nd series	0·78	1·11	0·50	0·41
3rd series	0·67	1·37	0·64	0·69
4th series	0·44	0·97	0·96	0·76
3. Co 313				
1st series	0·72	0·79	0·63	0·65
2nd series	0·80	0·87	0·84	0·61
3rd series	0·46	0·66	0·54	0·43
4th series	0·54	0·64	0·61	0·62

TABLE VI—*contd.*

Period	7-30 to 9-30 A.M.	9-30 to 11-30 A.M.	11-30 A.M. to 2-0 P.M.	2-0 to 4-0 P.M.
II. Mid-season group				
1. Co 213				
1st series	1·90	2·41	1·86	1·62
2nd series	0·76	0·98	0·66	0·45
3rd series	0·31	0·20	1·10	0·36
4th series	0·29	0·61	0·79	0·51
2. Co 210				
1st series	0·75	0·91	0·68	1·31
2nd series	0·74	0·86	0·69	0·70
3rd series	0·64	1·33	0·57	0·83
4th series	0·21	0·51	0·26	0·22
3. Co 356				
1st series	1·13	1·14	0·903	1·12
2nd series	1·11	1·33	0·62	0·70
3rd series	0·60	1·05	1·10	1·09
4th series	0·43	0·62	0·62	0·58
III. Late group				
1. Co 331				
1st series	0·91	0·94	0·59	0·71
2nd series	0·44	0·78	1·03	0·97
3rd series	0·53	0·77	0·55	0·78
4th series	0·60	0·74	0·75	0·52
2. Co 326				
1st series	0·78	1·36	0·70	0·87
2nd series	0·52	0·87	0·73	0·49
3rd series	0·51	0·65	0·63	0·75
4th series . . .	0·53	0·51	0·93	0·45

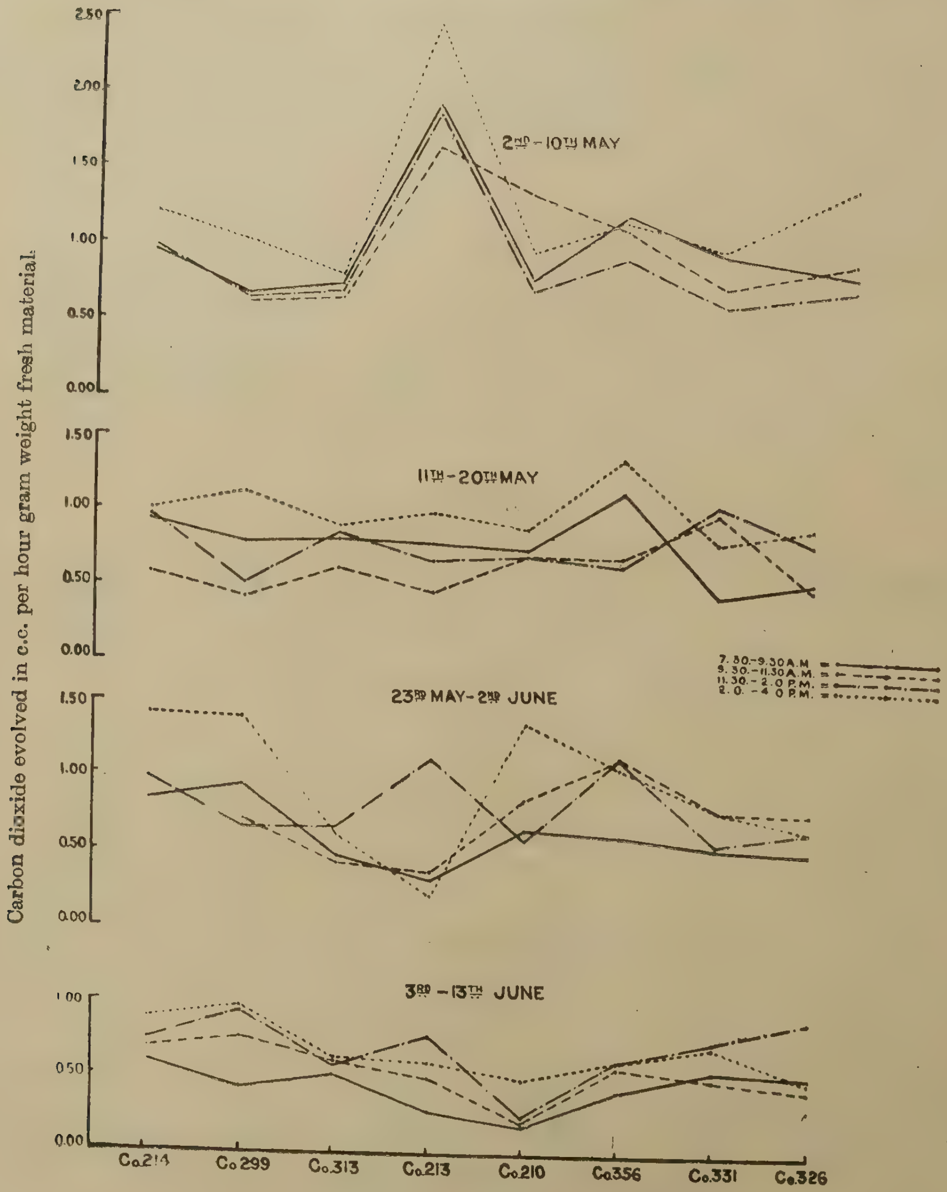


FIG. 4. Respiratory activity of varieties

4. In the morning hours when the disturbing influence of factors like temperature is comparatively little, as it usually lies within the optimum range between the hours of 7-30 A.M. to 9-30 A.M. (Tables II-V), it is expected that the functional response shown by plants would not vary much. The results obtained during this period could, therefore, be taken as fairly constant and comparable. The representation of the data (Table VII) on this basis brings out three distinct types of curves (Fig. 5).

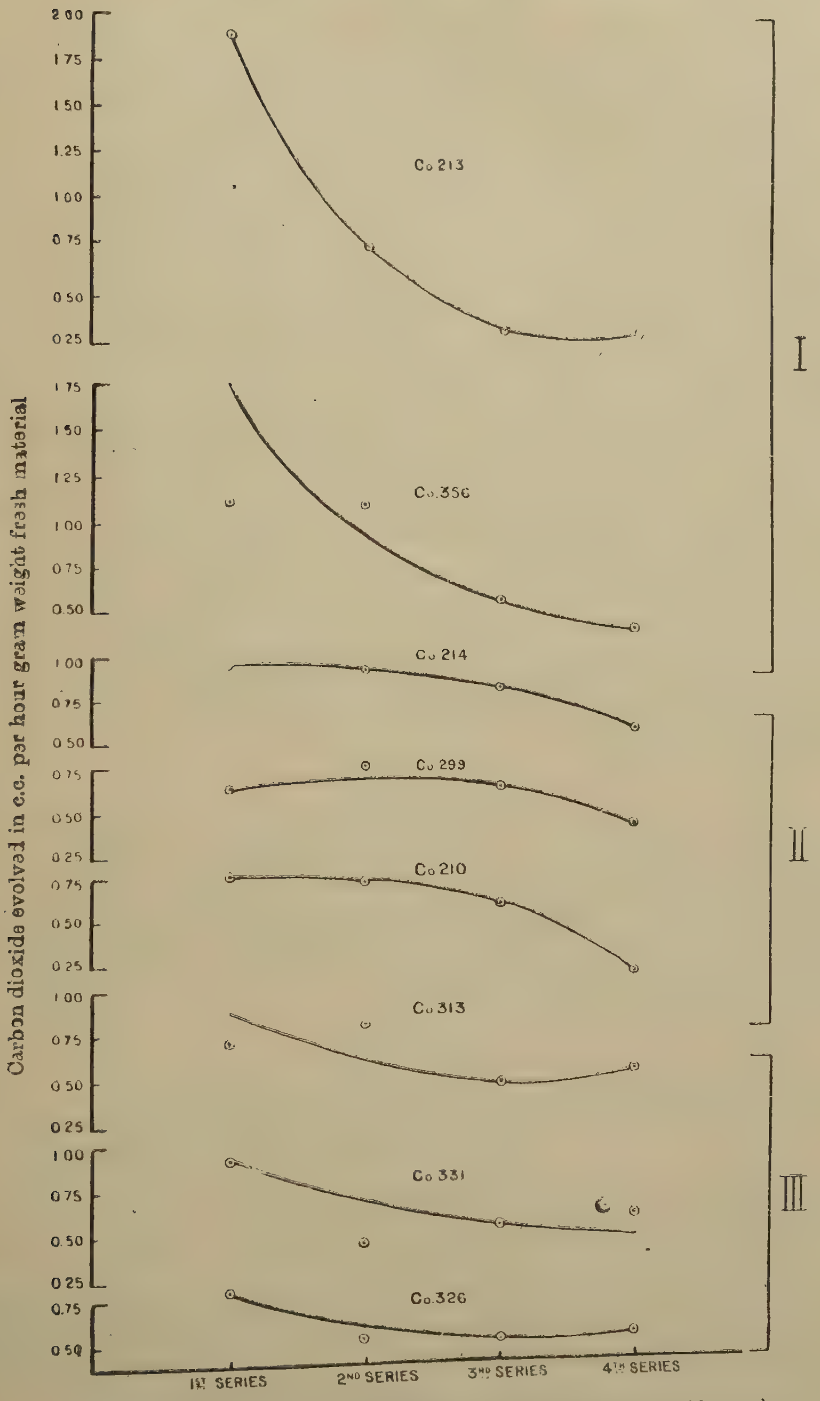


Fig. 5. Impress of advancing season on respiration (at 8-30 A.M.)

TABLE VII

Respiration rate in c.c. per hour per gram fresh weight between 7-30 A.M. and 9-30 A.M.

Serial No.	Period of observation	Varieties							
		Co 213	Co 356	Co 214	Co 299	Co 210	Co 313	Co 331	Co 326
1	2nd—10th May . .	1·90	1·13	0·94	0·65	0·76	0·72	0·91	0·78
2	11th—20th May . .	0·75	1·11	0·93	0·78	0·74	0·80	0·44	0·52
3	23rd May—2nd June . .	0·31	0·60	0·84	0·67	0·64	0·46	0·53	0·51
4	3rd—13th June . .	0·29	0·43	0·61	0·44	0·21	0·54	0·60	0·53

The first type is a regular steep convex to start with but tends almost to flatten at the other end. The second is very moderately concave, the fall being slight and long delayed. In the third type the curve is moderately convex which is composed of a slight steep initial decline followed by a moderate rectilinear course. In constructing these curves a few of the points have been left off as abnormal on both sides of the line but the general body of the data is such that definite interpretation can be put on the course of metabolism in different varieties. The variation in the differential response, however, cannot be regarded as dominated by one critical factor such as temperature but it has to be viewed as resultant of complexus of both environmental and edaphic factors.

IV. DISCUSSION

According to the law of 'definite optima' [Willcox, 1930] optimum growth or any other physiological phenomenon of a plant crop is a fixed one. Laboratory studies into the effect of temperature on the rate of metabolic activity have shown (Table VIII) that the maximum rate of respiratory activity is exhibited at 38° C. (100·4°F.) while it shows a distinct fall when the temperatures rise above 40° C. (104°F.).

TABLE VIII

Respiration rate in c.c. in relation to temperature

Variety	Temperature in degrees centigrade				
	30	35	38	40	45
Co 210	0·275	0·461	0·720	0·680	0·566
Co 213	0·180	0·326	0·441	0·441	0·387

It, therefore, follows that the optimum temperature for respiration lies below 38° C. As observed by Willcox [1930] the most favourable temperature for the growth of sugarcane is about 32° C. (90° F.). This temperature in the respiration studies described above has been usually prevalent during the morning hours between 7-30 A.M. and 9-30 A.M. and the respiration process at this time can be reckoned to be at its optimum. During the next two hours the temperatures rise invariably above 90° F. but they are usually below 104° F. It is, therefore, that respiratory activity at this period of the day is at its maximum. After this period, a considerable fall in the rate of respiration is generally observed and this is attributable to the high temperatures lying between 104° F. and 110° F. that prevail during noon hours in summer in Bihar. In the afternoon hours only when high temperatures were maintained the fall invariably was accentuated, otherwise a distinct tendency towards the revival of the normal physiological activity in the plant was noticed.

2. While working *in situ* it was observed that varieties with higher concentrations of chlorophyll exhibited narrower range of fluctuations in their respiratory activity (Figs. 2, 3) as compared to those that possessed lower chlorophyll content (Table IX). This would suggest that higher concentrations of chlorophyll afford greater stability to the vital processes of the plant. The exact contribution that is made towards this stability by different concentrations of chlorophyll and their reaction, if any, in the differential response of heat and light, however, yet remains to be investigated.

TABLE IX

Average percentage chlorophyll in functioning leaves of different varieties during May*

Serial No.	Varieties	Percentage chlorophyll
1	Co 213	0·373
2	Co 299	0·395
3	Co 210	0·419
4	Co 356 (Sorghum hybrid)	0·366
5	Co 326	0·462
6	Co 331	0·491
7	Co 214	0·501
8	Co 313	0·542

---

* The estimation of chlorophyll was made by the method advocated by Sprague and Toxler [1928] and the data are the average results of three determinations made in each case.

3. As has already been stated, in the beginning of hot weather the environment for plant growth is not so unfavourable, for only a few factors are in prominence and as such the varieties display usually narrow fluctuations in their metabolic activity (Table II). But, subsequently, as the environment becomes exacting, due to other factors like depletion of soil moisture (Table X) coming into play, these fluctuations are rendered more pronounced (Tables III and IV). With the passage of time, however, the varieties get adapted to the changed environment and the course of changes in the respiratory function (Table V) becomes more tame and less wide. Essentially all plants are adaptive in their constitution. Only some are more responsive than the others.

TABLE X

Soil-moisture content through the hot weather

Depth of sampling (inches)	Date of sampling (1935)			Remarks
	8th April (per cent)	9th May (per cent)	27th May (per cent)	
0—6	8·60	5·61	3·35*	*Asterisked figures relate to a sandy loam sample while others closely resembled the calcareous silt soil type most commonly met with in North Bihar.
7—12	11·97	11·95	9·90	
13—18	15·12	13·27	10·83	
19—24	16·45	15·83	12·86	

4. A detailed analysis of the curves (Fig. 5) indicates that in the first type both Co 213 and Co 356 exhibit an initial high rate of respiration but as the season advances they rapidly cut short their metabolism to a low level. Evidently these two varieties take the stress very keenly during the early part of the season although they tend to adapt themselves to environment later. In the second type the normal rate of respiration is maintained for a fairly long period and the varieties begin to yield to the stress only towards the latter part of the hot weather but the rate of respiration even then falls rather slowly so that the varieties namely, Co 214, Co 299 and Co 210 falling under this type appear to be better placed from the point of view of withstanding hot weather than those in the first one. The third type shows only slow and slight deviations from the normal respiratory function and the three varieties namely, Co 313, Co 331 and Co 326 in this type suffer from hot weather but little. There would thus appear to be a fair degree of correlation between the magnitude of depression in the respiration rate and the drought resistance of varieties.

V. Summary

Respiration studies on eight prominent sugarcane varieties were conducted during an advancing hot weather to study the effect of increasing drought and the response to it shown by different varieties under test. The results that have emerged are mentioned below :—

1. During the day, respiration rate was low in the morning ; it rose with the rise in temperature till the latter became supra-optimal (about 2-0 P.M.) when this rate fell considerably, the plant tending to regain its normal function with the return of favourable temperatures in the evening.

2. Of the varieties under test some were observed to be more consistent and less fluctuating in the periodic rate of respiration than the others. Co 213 was found to be most susceptible while Co 313 was least affected. Other varieties ranged themselves between these two extremes in the following ascending order namely, Co 299, Co 210, Co 356, Co 326, Co 331 and Co 214.

Varieties with higher concentrations of chlorophyll were observed to possess narrower range of fluctuations in their respiratory activity as compared to those with lower ones, suggesting that higher concentrations afforded greater stability to the vital processes of the plant.

3. In the beginning of hot weather the two-hourly fluctuations in the respiratory activity during the day were fairly consistent but as the hot weather advanced these fluctuations became more pronounced, so much so that in the third series (23rd May to 2nd June) they were the highest recorded. With the passage of time and possibly through adaptation they narrowed down considerably later in the season.

4. A fair degree of correlation seemed to exist between the magnitude of depression in the respiration rate and the acknowledged drought resistance of different varieties.

VI. Acknowledgments

The authors are indebted to the Imperial Council of Agricultural Research, under whose scheme for sugarcane research in Bihar and Orissa the work has been carried out.

REFERENCES

Blackman, F. F. and Colleagues (1928). *Trans. Roy. Soc. B.* **53**, 412-445

Luthra, J. C. and Cheema, I. S. (1931). *Ind. J. Agric. Sci.* **1**, 695-698

Sprague, H. B. and Toxler, L. B. (1928). *Sci.* **67**, 167-169

Willcox, W. O. (1930). 'Principles of Agrobiology', Palmer Publishing Corporation, N. Y., pp. 37-38

SOIL UNIFORMITY TRIALS IN THE PUNJAB. I

BY

P. E. LANDER, M.A., D.Sc., F.I.C., I.A.S.
Agricultural Chemist to Government, Punjab, Lyallpur
RAMJI NARAIN, Ph.D., D.Sc.
Assistant to the Agricultural Chemist, Punjab

AND

AZMAT SINGH, L.Ag.
Research Assistant, Agricultural College, Lyallpur

(Received for publication on 30th July 1937)

(With seven text-figures)

Introduction

The usefulness of statistical methods in interpreting the results of field experiments is now fully recognised by agricultural workers in the conduct of their trials. It is essential therefore that the design of experiments should be such that the data obtained can be examined by suitable statistical methods. Fisher's method of analysis of variance which can be applied for interpreting the results obtained from both Randomised Block and the Latin Square methods of layout—the two designs of field experiments which are generally adopted these days—by dividing the total variation in the yield of plots into a number of component parts, makes it possible for the experimenter to eliminate some of the major differences due to soil heterogeneity and thus enables him to make an unbiassed and valid estimate of the error for testing the significance of different treatments in an experiment. In some agricultural experiments, however, the residual error after this elimination, may still remain so high that even a high percentage difference between different treatments may not be significant. Vaidyanathan [1936], while examining some of the results obtained from agricultural experiments recently carried out in India, has observed cases where a percentage difference as high as thirty between different treatments was found to be non-significant. These differences are mostly due to random or chance errors within the blocks which must be reduced before differences in yield due to a variety of factors may become significant. This may be done in two ways :—

(*a*) By growing exhaustive crops before starting the actual trials, and, (*b*) By the application of suitable statistical methods,

depending upon whether these fertility differences result from casual or inherent causes.

The casual variation is the result of the interaction of a number of temporary factors affecting the whole or part of any one or more plots within the blocks, such as partial or unequal manuring of the area in the past, residual effects of organic remains, removal of rich surface soil during levelling operations, competition between growing crops and weeds, and the differential effects of seasons, etc. This casual and superficial fertility, as may be readily seen, may possibly be removed by growing one or more exhaustive crops.

The inherent diversity in soil fertility may result from differences in mechanical composition of the upper and lower soil strata at various places, or the presence in different amounts of less readily available chemical substances. Inherent variations can be partly eliminated by following the method of covariance, which aims at increasing the precision of the experiment by carrying out a preliminary uniformity trial and employing the figures obtained therefrom to correct the yield data of the plot when under experiment. This, however, depends on the extent to which the constancy of the plots in their relative productivity during different years and under different climatic conditions and crops will be maintained.

HISTORICAL

Harris in a number of papers published in 1920 and 1928, employing the method of coefficient of correlation between the yielding powers of adjacent plots, demonstrated that soil heterogeneity—as judged from plot yields—is a phenomenon of almost universal occurrence, even on comparatively small areas. For calculating the coefficient of correlation he divided the entire area into a number of small plots, called ' ultimate plots', and made various combinations by combining the yields of contiguous plots. Lander [1925] used a much simpler method for indicating the average cropping power of the area selected for experiments with sewage water from the Lyallpur City. He planned soil-fertility contour maps locating average plot yields from his ' uniformity crops ' at the centre of the plots, the points representing yields between the limits actually obtained being fixed at corresponding distances and joined together according to the method adopted by the Meteorological Department in representing graphically the weather phenomena at various places. The method is helpful in showing at a glance the relative approximate fertility of various places in the field with respect to the crop grown and also whether this fertility exists in a systematic manner or in random patches. Fisher [1930] suggested that in cases where the preliminary yields of plots before starting the actual experiment are known, increased precision may be obtained in certain cases by utilizing the method of covariance for correcting the standard error of the experiment in relation to that obtained in the previous year. Sanders [1930] applied this method to annual crops and showed that of the two cases examined, the precision of the experiment was increased only in one. The method has subsequently been employed mostly in dealing with the data from perennial crops. For example, Eden [1931] and Vaidyanathan [1934] in the case of tea, Cheesman and Pound [1932] with cocoa, and Murray [1934] with rubber, have obtained results indicating a substantial reduction of error by this method. De Vertenil [1934], however, dealing with yield data from coconut trees under different manurial treatments, could obtain only a slight increase in precision, which was not sufficient to cause any change in the conclusions from the results as they stood before the application of this method. Bose [1935] used this method in studying some of his data for wheat, barley and lentils. He found that the precision of the comparison did increase to a certain extent but it was so small as hardly to affect the conclusions otherwise arrived at.

OBJECT

In 1928 it was decided to start a fresh series of manurial experiments at various agricultural stations, but with preliminary uniformity trials at each place with the following objects :—

1. To measure the variations in soil fertility of the land selected, and to map these in a simple and concise manner with a view to the application of the information so obtained in the interpretation of the data collected from subsequent manurial trials.

2. To see how far, by growing exhaustive crops such as *chari* and wheat, it was possible to render the area more uniform for the final field trials.

3. To see how far the results obtained from these uniformity trials could be used in the standardisation of field-plot technique with special reference to the land under experiment.

The results obtained from these uniformity trials and the extent to which the above-mentioned objects have been attained are described in the present paper. The data which have been collected during their course have also been used to study the application of the method of covariance to annual crops. The literature cited above shows that although this method has been applied successfully in dealing with data from perennial crops, its application to annual crops has so far been limited and that the conclusions arrived at do not rest on any detailed and exhaustive examination of the application of this method to a number of crops grown in different seasons and at different places. It is, however, hoped that the data from these trials will supply more definite information than has so far been available.

THE PUNJAB TRIALS

Soil-uniformity trials in the Punjab were carried out at a number of agricultural stations, *viz.*, (1) Rawalpindi, (2) Lyallpur, (3) Gurdaspur,

(4) Hansi, (5) Montgomery and (6) Sargodha. The following statement shows the area reserved at each station, the size of plots and the crops grown :—

Name of station	Area in acres	Plot size (acres)	Crops and years							Remarks
			1929		1930		1931		1932	
			Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	
Rawalpindi	25	1/11	...	Wheat*	*Chari***	Wheat	...	Wheat	...	
Lyallpur	12	1/11	*Chari*	Wheat	*Chari*	...	*Chari*	...	...	
Gurdaspur	12	1/10	*Chari*	Gram†	*Chari*	...	...	Wheat	...	
Hansi	25	1/10	...	...	*Chari*	...	*Chari*	...	...	
Montgomery	20	1/13	...	...	...	...	...	Wheat	*Chari*	
argodha	25	1/10	...	Wheat	Maize‡	Wheat	Maize	...	...	In block A
			...	Wheat	*Chari*	Wheat	...	...	...	In block B
			Chari	Wheat	...	Wheat	...	...	...	In block C
			...	Wheat	*Chari*	Wheat	...	...	...	In block D
			Chari	Wheat	...	Wheat	...	...	...	In block E

**Triticum vulgare*

***Andropogon Sorghum*

†*Cicerarietinum*

‡ *Zea Mays*

Since the data collected are very numerous it is not possible to examine the whole of them in the course of a single article without making it too elaborate. In the present paper, therefore, the data obtained from Rawalpindi have been examined in detail, reserving the discussion of those from other stations for a subsequent publication.

The trials were laid out on a field scale so that the results obtained may be convincing and of direct use to the practical farmer. At each place a number of fields were combined to give one compact block. At most of the above stations, the fields comprising the final manurial block had previously been used for growing different crops under different manurial and cultural treatments. In some cases they were under cultivation by tenants and no records of their yielding capacity were available. For instance, at Rawalpindi the farm had only recently been brought under direct cultivation, and even the level of the land available for the trials was defective. The size and shape of the ultimate plots pertaining to any particular station were determined by certain practical considerations, such as the dimensions and shape of the area available, the existing position of irrigation channels, roads, etc. The land selected was levelled and laid out in plots according to the layout plan prepared for each station and as far as possible, previous farming experience regarding the fertility of the various fields composing the final block, aided by eye observation about their condition at the time the trials were started, was fully utilized in preparing the new layout plans. Long and narrow strips with a length-to-breadth ratio of ten to one were used, and this was adhered to in all cases, as far as was found to be practicable.

During the period over which these test crops were grown, all the plots, till the time of harvesting, received identical treatments with respect to cultural operations, sowing, irrigation, etc., the object being to eliminate all variation due to these extraneous causes.

Since crop yields are influenced to an appreciable extent by the mechanical composition of the soil, the area selected at each station was examined for any variation that might exist with respect to this factor. Samples representing the first and second foot layers of the soil were taken at a fairly large number of places scattered over the entire area and analysed for mechanical constituents. In case any portion of the soil was found to differ widely from the remaining area (as was the case at Lyallpur and Hansi), it was excluded from the land reserved for these experiments.

The following plan has been adopted for examining the data available from Rawalpindi :

(*i*) By constructing soil-fertility curves to show the comparative yields for all the plots within any block and their deviation from the line of mean yield for all the blocks.

(*ii*) By mapping soil heterogeneity in the shape of fertility contours which show at a glance differences in yield pertaining to different portions of the entire area.

(*iii*) By determining the coefficients of variation of the yields of all the plots within each block.

(*iv*) By the 'analysis of variance', to show the standard error per plot for each crop and the application of the method of covariance for reducing such errors, thus increasing the precision of the experiment.

(*v*) By an examination of the data after arranging them in the form of a Latin square so as to obtain information about the drift of soil fertility and the suitability of the layout proposed for final trials.

(*vi*) By arranging the plot yields in different ways so as to provide increasing numbers of replications and analysing the data thus obtained with a view to getting some information regarding the field-plot technique.

Details of the layout as adopted are shown in the plan (Fig. 1).

As will be seen, the area consisted of five fields D_4, D_5, D_6, D_7 and D_8, each comprising five acres of land. Each of these five fields was divided into three sub-divisions A, B and C, by means of two strong bunds each five feet wide running from east to west. These three sub-divisions were thus divided into five blocks, each consisting of thirteen experimental plots with fourteen non-experimental strips five feet wide separating each one of the experimental plots from the other. The dimensions of the experimental plots were 207 ft. 5 in. by 19 ft. 1 in. The southern third of the entire area, henceforth designated as sub-division A, was reserved for experiments designed to ascertain the most suitable organic manure from the viewpoint of moisture conservation and crop yield, whereas sub-divisions B and C on the north side were reserved for studying the effects on crop yields of the application of various artificial fertilizers both in the presence and absence of added organic matter.

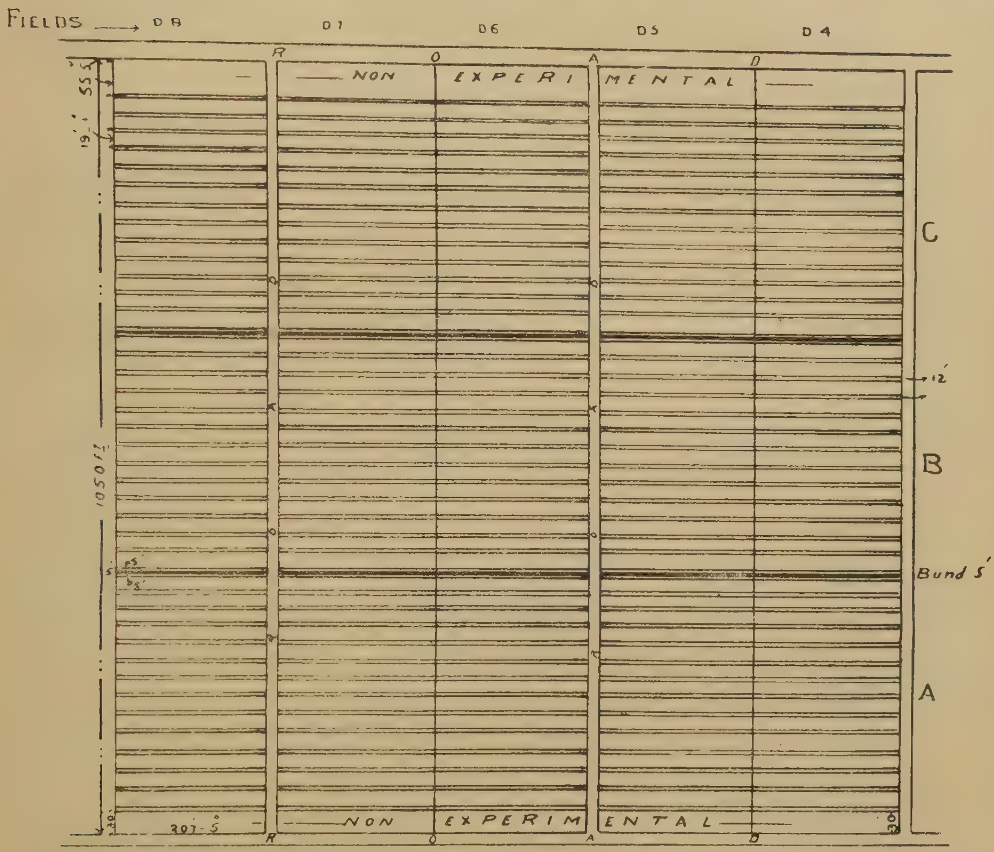

FIELDS → D8
D7
D6
D5
D4
R
O
A
D
NON EXPERIMENTAL
NON EXPERIMENTAL
C
B
A
12'
Bund 5'
1050 ft
19'
5.5'
30'
307.5'

FIG. 1. Layout plan of manurial experiments at Rawalpindi Agricultural Station (*Barani*)

One point concerning the area under these experiments deserves special mention. Before it was brought under cultivation there used to be in field D_4, a low-lying road-way running from south to north and leaving the field towards the eastern side near the southern portion of sub-division C. After the area had been acquired for these experiments, this low-lying portion of field D_4 was filled to a level with the rest of the area with soil brought from outside.

EXAMINATION OF THE YIELD DATA

1. The yields of each plot obtained during different years are shown in Table I.

TABLE I

Yield in maunds per acre from different plots for the four test crops grown at Rawalpindi

Plot Nos. (north to south)	Sub-divisions														
	A					B					C				
	D_8	D_7	D_6	D_5	D_4	D_8	D_7	D_6	D_5	D_4	D_8	D_7	D_6	D_5	D_4
							I. Wheat 1929-30								
1	9·2	14·7	22·4	20·8	25·7	12·5	21·6	29·9	25·1	27·6	6·7	9·4	11·8	10·3	8·9
2	9·8	15·3	25·4	18·2	25·5	16·4	25·2	24·0	25·3	31·3	8·6	12·0	14·1	17·1	10·0
3	9·6	16·7	23·0	13·3	25·3	14·1	22·9	21·5	23·7	30·7	8·3	10·5	13·8	17·6	10·9
4	10·0	19·1	26·1	15·1	21·5	14·5	18·0	22·3	20·7	32·5	8·1	11·3	14·2	18·4	11·4
5	9·4	15·9	24·4	15·1	27·8	15·1	14·5	21·8	18·7	24·6	8·2	10·1	16·3	18·0	14·2
6	9·8	19·4	23·4	15·7	23·4	11·1	14·1	22·8	19·3	30·1	9·7	9·0	24·8	18·4	14·6
7	10·2	17·3	18·5	14·5	26·1	11·7	13·0	23·7	18·2	29·2	9·0	9·7	22·0	23·9	17·7
8	10·3	16·4	17·5	15·7	24·5	10·3	12·6	22·8	19·4	27·1	9·4	11·6	20·4	25·4	17·5
9	13·6	15·0	15·1	15·6	25·6	11·0	12·3	23·3	21·6	24·2	6·8	13·6	24·6	23·2	21·8
10	12·1	15·4	16·9	13·8	23·5	9·7	13·8	20·7	20·8	26·1	8·8	12·7	27·5	24·8	23·9
11	9·8	15·7	16·3	17·8	24·7	10·3	12·0	21·9	24·4	31·0	7·3	12·3	30·1	22·8	23·0
12	12·9	14·7	17·3	14·7	26·4	10·9	13·8	22·2	26·1	25·1	10·0	14·3	31·5	24·1	22·6
13	16·9	19·1	18·2	15·8	30·1	9·4	14·6	23·8	23·7	31·0	12·5	16·6	30·4	25·7	23·4
							II. Chari *1930*								
1	56·1	56·4	59·1	56·4	63·3	48·1	64·6	70·9	59·7	55·0	41·5	52·8	48·1	58·9	57·2
2	48·9	48·1	61·9	77·0	63·3	51·4	55·3	62·7	56·7	56·1	42·6	59·9	61·6	61·6	55·0
3	48·4	45·4	52·3	70·1	68·8	48·1	59·7	61·6	57·2	55·0	45·7	52·8	63·3	57·8	57·2
4	46·5	52·3	67·4	74·3	64·6	45·7	60·5	60·8	58·0	60·2	42·4	51·7	61·9	56·1	57·5
5	47·9	51·4	56·4	74·3	60·5	59·7	55·0	59·1	65·2	66·0	38·2	58·3	63·5	53·9	55·3
6	52·8	59·1	71·5	68·8	70·1	56·7	53·1	57·2	66·8	63·3	42·4	58·3	67·8	50·6	66·6
7	59·4	60·5	67·4	74·3	56·9	53·9	50·1	60·5	67·1	67·4	44·0	62·7	65·6	51·7	57·8
8	59·4	56·4	66·0	75·6	56·4	49·8	54·2	64·6	67·1	68·8	44·0	64·4	56·4	50·1	54·2
9	59·7	56·4	64·6	67·4	58·3	50·6	57·2	58·3	64·6	61·9	48·9	56·7	55·0	50·9	57·5
10	55·6	53·6	68·8	67·4	58·9	52·8	46·2	68·2	63·3	66·0	55·0	58·6	51·4	51·7	56·1
11	61·6	59·1	68·8	71·6	56·4	53·4	54·2	65·2	60·5	73·4	53·4	59·9	49·5	54·5	57·2
12	54·2	64·6	74·3	67·4	55·0	46·8	54·5	65·7	64·1	64·4	56·4	53·1	45·9	48·7	54·2
13	49·2	61·9	70·1	70·1	56·4	53·9	59·1	62·2	63·5	60·8	63·8	46·5	49·5	46·2	63·5

III. *Wheat 1931-32*

1	15·4	13·8	17·9	21·5	25·6	20·9	17·9	26·4	26·1	30·0	17·1	15·4	22·0	26·4	24·2
2	12·1	17·3	17·9	27·5	28·3	15·1	18·2	22·0	27·5	29·7	18·4	15·4	21·2	24·2	28·9
3	14·6	17·3	19·3	27·5	27·5	12·9	22·6	19·8	26·7	27·2	17·9	16·8	22·0	23·1	33·0
4	12·4	14·3	18·7	28·9	27·5	20·6	22·6	19·8	27·8	30·0	19·3	16·2	22·6	22·0	27·2
5	13·5	15·1	18·4	28·1	25·9	18·7	20·6	17·7	25·3	28·3	20·9	19·3	19·0	22·0	34·4
6	13·2	16·2	22·0	27·5	27·3	16·8	22·8	24·2	25·6	32·5	20·6	22·0	17·6	21·5	30·3
7	15·4	16·2	22·0	31·6	25·3	19·0	19·3	21·5	25·6	34·7	21·5	21·5	18·4	22·0	32·2
8	13·8	14·3	24·8	27·5	28·3	18·4	19·5	22·6	25·0	38·5	24·5	21·5	16·8	23·1	32·2
9	15·7	15·1	20·9	30·3	31·4	17·3	17·9	24·2	25·3	38·5	28·1	18·7	17·3	24·2	31·6
10	16·0	13·8	25·6	28·9	30·8	19·3	19·8	23·4	25·9	38·8	30·5	18·4	18·4	22·0	35·5
11	17·9	15·4	20·6	27·5	31·4	16·5	16·5	20·4	25·3	41·3	26·1	19·3	16·2	22·0	32·5
12	17·9	16·2	20·9	29·2	31·9	19·3	17·3	19·5	25·6	38·2	26·7	18·2	17·1	23·4	34·7
13	15·7	16·0	22·6	22·8	23·3	17·3	17·3	20·1	25·0	41·5	27·5	19·5	14·6	22·0	42·4

IV. *Wheat 1932-33*

1	8·3	8·8	16·0	11·3	13·5	13·8	12·7	21·5	15·1	13·8	8·3	8.8	8·8	6·3	13 2
2	14·3	6·9	19·3	12·9	14·0	14·6	20·4	21·5	16·5	16·8	8·5	11.3	11·0	10·2	11·3
3	13·2	17·3	23·7	15·1	13·8	6·9	13·5	10·5	16·8	14·3	7·2	11.6	12·1	12·2	12 9
4	14·9	14·3	18·2	13·2	14·6	14·0	18·7	14·6	17·6	16·8	6·6	6.3	7·7	10·5	11·0
5	13·2	16·8	19·8	12·7	18·2	16·8	15·4	16·5	14·6	18·2	7·4	10·5	9·4	9·9	13·8
6	12·4	22·6	20·4	18·2	17·3	9·9	14·9	19·8	8·8	19·3	8·5	9·1	11·6	7·4	13·8
7	17·3	23·1	15·1	13·8	17·1	17·1	14·6	17·9	8·5	20·1	9·9	9·1	14·3	18·2	15·4
8	20·9	21·2	12·4	17·1	17·6	16·0	12·9	15·4	6·3	17·3	8·3	10·5	15·8	17·9	16·0
9	19·0	15·4	8·5	14·0	15·7	11·6	10·7	15·4	8·3	15·4	9·1	6·6	9·4	15·1	16·5
10	20·1	18·7	14·0	14·0	17·6	11·8	12·7	17·3	11·6	19·8	10·5	8·8	15·1	13·8	20·1
11	19·0	16·0	9·4	13·8	18·4	12·4	6·3	13·5	10·5	16·8	11·3	7·4	9·1	12·1	18·2
12	19·3	18·2	9·4	12·7	18·7	11·3	9·6	17·6	12·4	14·0	14·0	11·3	16·0	13·2	25·3
13	21·7	17·9	9·6	15·1	32·7	13·5	10·2	17·3	9·1	14·9	14·0	10·7	22·3	11·3	17·9

It is apparent that the weight of *chari* obtained from any plot is about three to four times the weight of wheat obtained from the same plot in any one year. It is inconvenient for the purpose of comparison to represent in the form of curves two sets of figures so widely apart. Therefore, in order to bring the data for the two crops to a more uniform basis* the yield of wheat from each plot has been multiplied by a factor equivalent to the ratio between the mean weight of *chari* from all the plots to the mean weight of wheat from the same plots expressed as unity. Thus the mean weight of *chari* from all the plots in sub-division A was 61·2 maunds per acre and the mean weight of wheat in 1929-30 from all the plots in the same sub-division was 17·8 maunds This gave a ratio of *chari* to wheat of 3·439 : 1 that year ; similarly 2·853 : 1 in 1931-32, and 3·825 : 1 in 1932-33. In order to obtain for comparison a more concise picture of the yields of wheat from individual plots, these were multiplied respectively by 3·439, 2·853 or 3·825, corresponding to the ratio obtained during any particular year in the manner described above. The yield figures for wheat from sub-divisions B and C during different years have also been multiplied by similar appropriate factors. The data thus obtained are referred to as 'adjusted' yields, and supply a more comprehensible set of figures for comparison than the actual yields of wheat. In this manner without changing the yield ratios for different plots during any year we obtain the same average plot yields during each of the four years the fertility tests were carried out. The actual yields for *chari*, and the adjusted yields for wheat for the four years from sub-divisions A, B, C are represented graphically as curves in Fig. 2.

2. For the purpose of mapping the soil-fertility contours, the entire area comprising the three sub-divisions A, B and C was treated as one single block. As has already been explained, this entire area was divided into fifteen separate blocks each of which was in turn sub-divided into thirteen plots or experimental strips. The yield of each of these strips is shown by a figure placed at the centre of each. The actual yields thus located differ from the mean yield of the whole area, and the various points at which the actual yields of these different plots were twenty, forty, and sixty, etc., per cent above or below the mean yield, have been fixed by interpolation between adjacent plots. These interpolated figures were then joined together to represent areas lying within a certain range of soil productivity. The contour maps shown in Figs. 3–6 were prepared in this manner. A glance at these diagrams shows that the yields from different areas receiving the same cultural and other treatments vary greatly, and that the yield from one and the same area was different in different years. These conclusions are in harmony with some of those arrived at by Harris and Bose under different soil and climatic conditions.

---

*Other methods of representation are possible, which have not been considered in this paper. [Ed.]

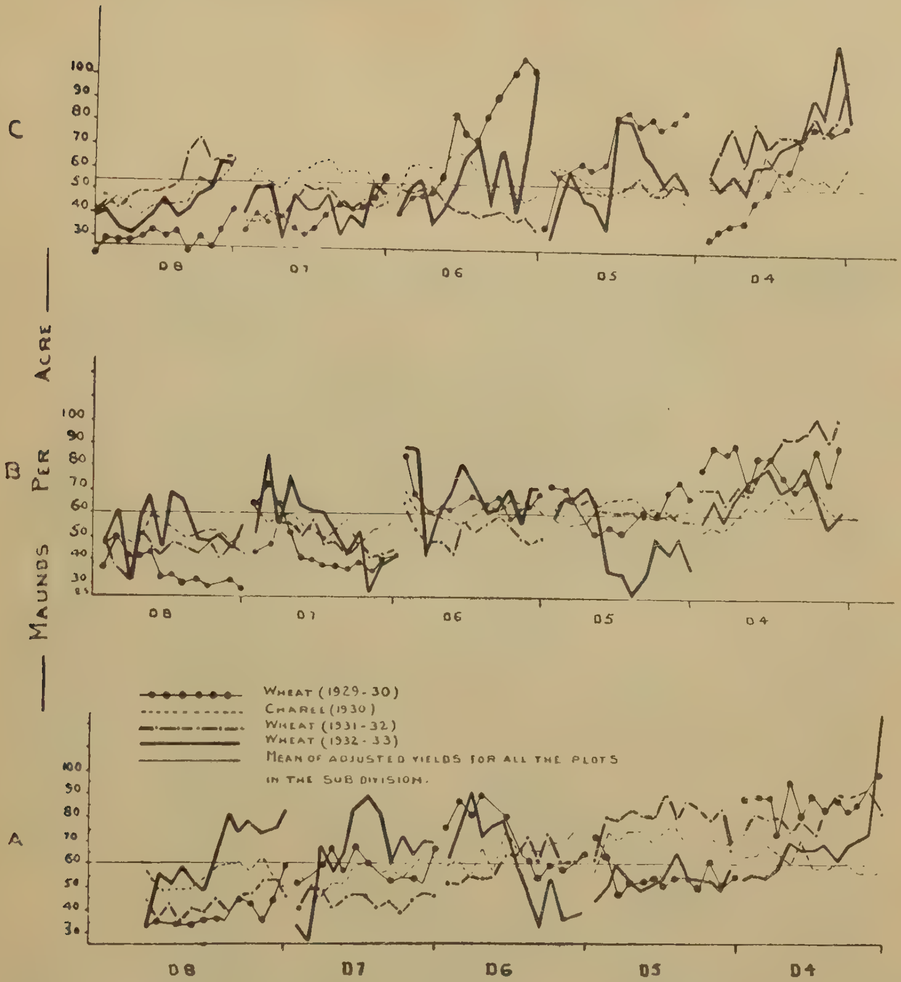


FIG. 2. Variations in yields from different plots for the four test crops. Plots north to south (1-13)⟶

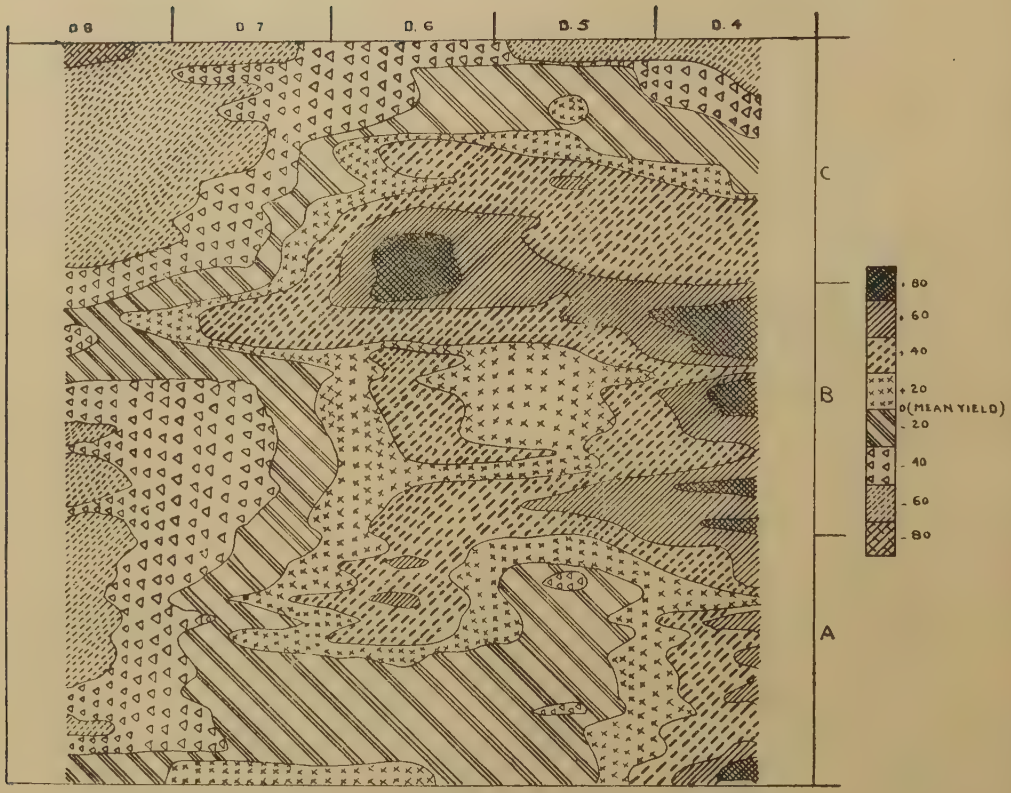

D 8
D 7
D. 6
D. 5
D. 4
C
B
A
+ 80
+ 60
+ 40
+ 20
0 (MEAN YIELD)
- 20
- 40
- 60
- 80

FIG. 3. Contour map based on yields of wheat (1929-30)

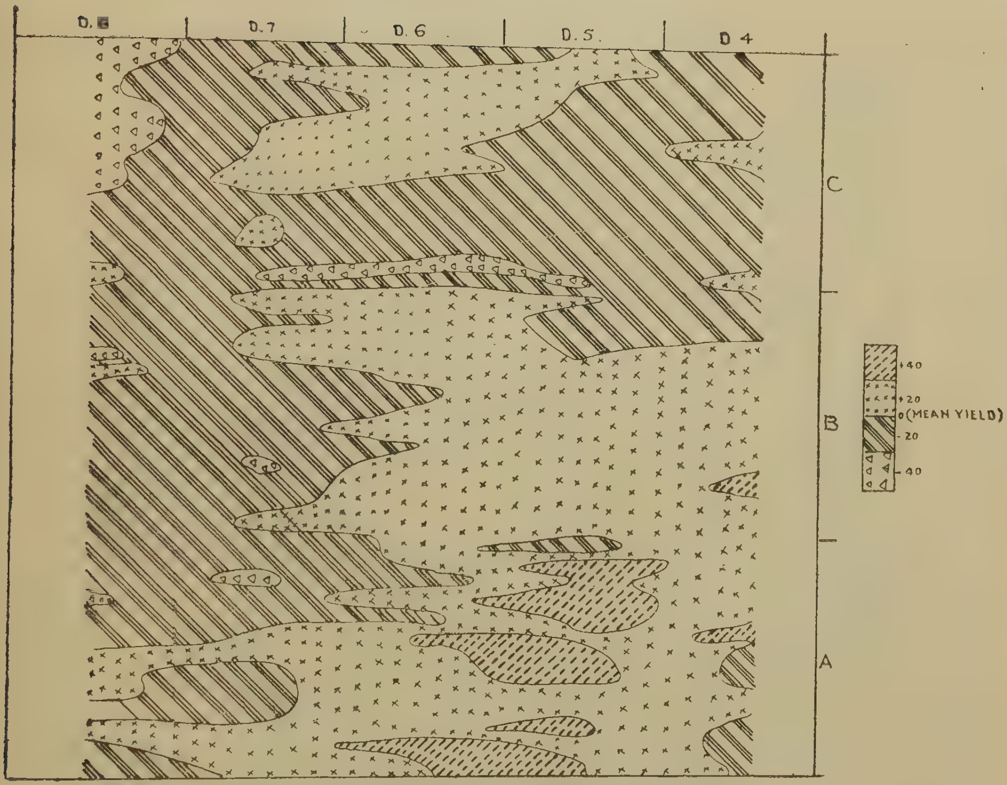

D. 8
D. 7
D. 6
D. 5
D 4
C
B
A
+40
+20
0 (MEAN YIELD)
- 20
- 40

FIG. 4. Contour map based on yields of *chari* (1930)

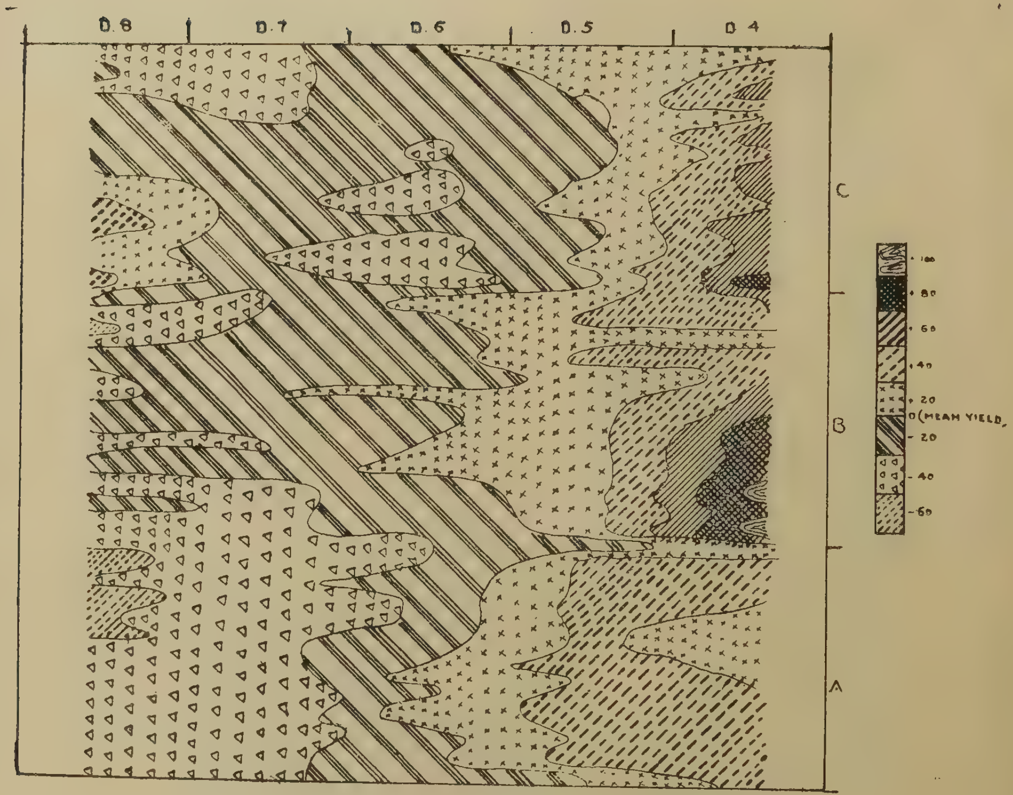

D.8
D.7
D.6
D.5
D.4
C
B
A
+ 100
+ 80
+ 60
+ 40
+ 20
0 (MEAN YIELD)
- 20
- 40
- 60

Fig. 5. Contour map based on yields of wheat (1931-32)

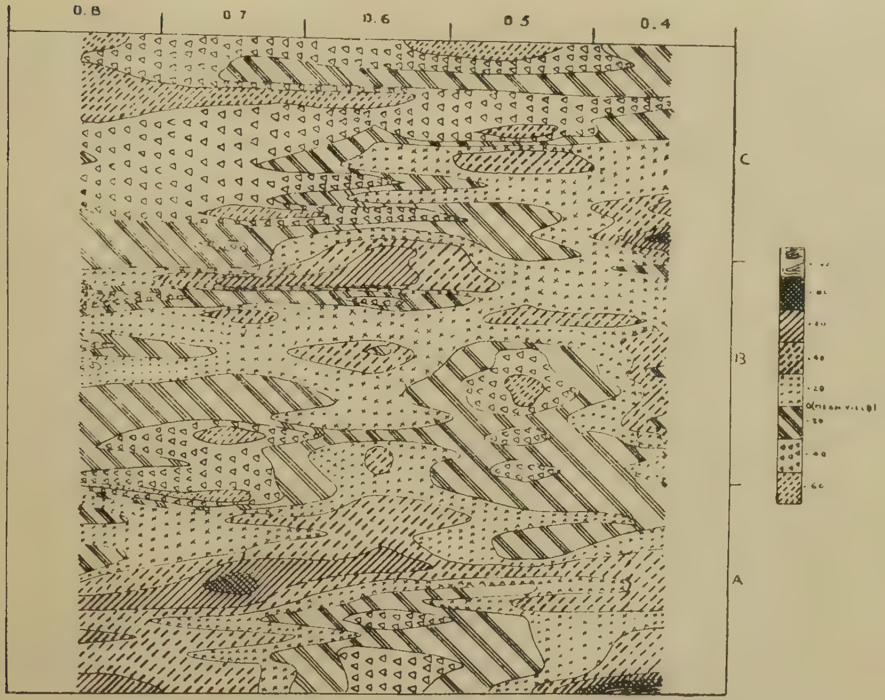


FIG. 6. Contour map based on yields of wheat (1932-33)

It will further be seen that the yields from all the plots in field D_4 throughout the period of the four years, with which the data presented in this paper deal, were as a general rule greater than the yields from plots in the other fields. The yields from D_7 and D_8 on the other hand were invariably low. This points to certain fixed soil characteristics in fields D_4, D_7 and D_8 which, in spite of the variations due to the effect of seasons, are indicative of inherent differences of soil fertility within the area. It has not been possible to bring the fertility of field D_4 to a level with that of fields D_7 and D_8, even after growing successively four crops, without any application of manures. It may be further noted that the nature of the crop exercises a great influence on the yields from different plots or fields. Whereas the yields of wheat from different plots in different blocks fluctuate widely about the mean value of the whole area, those of *chari* on the other hand are less variable and are very close to the line of average or mean yields (Fig. 2). This is also clear from a consideration of the fertility contours shown in Figs. 3-6 of which No. 4 shows the smallest variation. In this case the maximum variations are within a range of forty per cent of the mean value as compared with eighty per cent or more in the case of wheat produced during any year. It is evident, therefore, that soil heterogeneity as revealed by any one crop cannot be a true index of the subsequent behaviour of that area with respect to other crops. Even the same crop raised in different seasons has not shown any constancy as regards soil heterogeneity, for, as will be seen (Fig. 2) the wheat curves for different years do not run parallel with each other in any of the three sub-divisions. The positions of these curves with respect to the line of average fertility were different in different years, even when the crop grown in, say, two successive years was the same. This shows that the season exercises a much greater influence in modifying crop yields than any other casual factor would normally be expected to do.

Some other conclusions, though of minor importance, follow from a detailed examination of the yield diagrams (Figs. 2-6). For instance, the first wheat crop in field No. 5 and in the southern half of field D_6 of sub-division A gave a yield uniformly lower than the mean yield, while for these same fields the succeeding *chari* crop gave yields which were uniformly heavier than the mean. Judging from the yields obtained from the third and fourth test crops, field D_7 and the southern half of field D_8 of sub-division A supply a further illustration of the same tendency. Again, it may be noticed that in the case of a number of plots the yields during any one year were the reverse of those in the previous years, *i.e.* they become high where they were low and *vice versa*. This, however, is not a general observation, since there is also a fairly large number of cases in which the higher or the lower yields are maintained during the following year.

The above results confirm Harris's conclusions [1920] that an experimental field which might be demonstrated to be sensibly uniform for one crop or for one season might not prove to be so for another crop or in a different season. Bose [1936] from his study of the yields of barley, wheat, and lentils during successive years, also draws similar conclusions. A glance at the contour maps for the three crops given by him, however, shows a good deal of similarity, since in his case the fertility contour lines run, to a very pronounced degree, more or less parallel to the direction of the columns running from north to south. It is quite likely that this may be a special feature peculiar to the field on which Bose's experiments were carried out. In our case, however, as seen from Figs. 2-6, no such similarity has been noticed. On the basis of the results obtained, we are inclined to consider that soil uniformity trials are helpful in supplying information which can be useful in deciding only the general layout of the subsequent experiments. The yield data, however, from a test crop grown previous to the experiment, may not necessarily supply sufficient information on the basis of which one could decide the correct size and shape of the experimental plots to be laid out at that place or in a different locality, and to be put under a different crop in another season. In our case, even four test crops failed to give this information. Since fertility test crops are likely to supply only general information about the drift of soil fertility it would seem unnecessary to devote too much time and attention to these. In cases where this general information is already available, it would, in view of the results obtained by us, seem more profitable to start the experiment at once by adopting a layout which would yield data capable of statistical interpretation. In case previous experience of the land shows it to be of distinctly uneven fertility, an attempt to bring it to a more uniform level of fertility will serve no useful purpose and it will be advisable to reject such an area in favour of a more uniform one.

The information obtained from fertility diagrams, however, suffers from a certain limitation which can be best illustrated by taking a concrete example. The contour maps for the first fertility crop of wheat (Fig. 3) has been constructed on the basis of twenty per cent differences from the mean yield and its multiples. Thus the total fertility has been divided into eight different zones, each succeeding one differing from the previous one by a fertility indicated by a fall of twenty per cent calculated on the mean value. Now, considering the fertility of the plots within blocks D_7 and D_8 of this subdivision, we find from the contour diagram that about two-thirds of the plots in block D_8 lie within the same fertility zone. They are similar to each other in fertility although differing from the remaining one-third which, however, are of similar fertility as far as they are concerned. In the case of plots within block D_7 we also find that two-thirds of these, because they lie within the same fertility zone, must be regarded as of similar fertility but different from the remaining one-third which are, however, again similar as far as they are concerned themselves. This means that the extent of variability of the two sets of plots within each of these two blocks as judged by a consideration of their fertility contours is almost the same. If, however, the yields from two such sets of plots within a block lie on the two extremes of two successive zones of the fertility gradient, the extent of variation will necessarily be greater as compared with that when all the plot yields of a block tend to lie close together although in two different zones of fertility. The differences in the extent of variation in such cases can be expressed much better in terms of coefficients of variability. In the two cases mentioned above the coefficient of variability for plots lying within block D_8 is 20·44 and of those lying within block D_7 is 10·35. These differences cannot be illustrated so vividly in contour diagrams unless the limits of different fertility zones are considerably narrowed. This will, however, make them far too complicated. In addition, the coefficients of variability show the degree of dispersion of individual plot yields round the mean value. It was therefore decided to work out the coefficient of variability separately for each block.

3. *Coefficients of variability.*—As will be seen from the plan of the experiment the entire area at Rawalpindi was divided into three sub-divisions, each comprising five blocks of thirteen plots each, *i.e.* there are sixty-five plots in each sub-division. In order to compare, during different years, plot variations within blocks in any one of the three sub-divisions, coefficients of variability were worked out and these together with the mean yields are given in Table II.

TABLE II

Mean yield in maunds per acre and coefficient of variability of each block in different years

Name of crop	D_8		D_7		D_6		D_5		D_4	
	Mean yield	Coefficient of variability	Mean yield	Coefficient of variability	Mean yield	Coefficient of variability	Mean yield	Coefficient of variability	Mean yield	Coefficient of variability
					Sub-division A					
I. Wheat .	11·05	20·44	16·52	10·35	20·35	18·87	15·85	12·74	25·39	8·32
II. *Chari* .	53·82	9·75	55·79	9·87	65·28	9·64	70·35	7·60	60·69	8·14
III. Wheat .	14·89	12·45	15·47	7·69	20·89	11·91	27·55	9·68	28·42	8·05
IV. Wheat .	16·45	24·38	16·71	28·42	15·06	33·16	14·15	13·23	17·63	27·76
					Sub-division B					
I. Wheat .	12·08	18·63	16·03	27·67	23·13	9·75	22·08	12·50	28·50	10·03
II. *Chari* .	51·61	9·62	55·67	8·47	62·85	6·31	62·60	6·02	62·79	9·57
III. Wheat .	17·85	12·42	19·41	11·21	21·66	11·21	25·90	2·18	34·63	15·21
IV. Wheat .	13·05	21·90	13·28	28·20	16·83	18·39	12·01	31·42	16·96	12·88
					Sub-division C					
I. Wheat .	8·72	17·53	11·85	18·53	21·65	32·64	20·75	21·30	16·92	33·11
II. *Chari* .	47·56	15·64	56·59	7·33	56·89	13·11	52·29	8·38	57·64	6·38
III. Wheat .	23·01	19·28	18·63	11·99	18·71	13·45	22·92	6·01	32·24	13·60
IV. Wheat .	9·51	25·05	9·39	19·09	12·50	32·60	12·24	29·12	15·80	24·92

It will be seen from this that the general conclusions arrived at previously from a consideration of the diagrams are amply borne out. Of all the crops during the four seasons, the coefficients of variability for the *churi* crop were the smallest. These figures also show that whereas in the case of wheat grown during the season 1929-30, blocks D_4 and D_6 in sub-division C showed the greatest variabilities, in the case of the two succeeding crops, it was block D_8 of this sub-division which showed the maximum variation. Similarly block D_5 in sub-division B showed a remarkably low variability for wheat in 1931-32 but in the case of the wheat crop next season the variability within this block was greatest of all. Similar examples could be selected from other blocks in the three sub-divisions. In addition to their being widely apart, the differences in the order of the values of this constant for various crops in different years are a clear indication of the absence of any constancy in the fertility of the plots within any of the blocks. The coefficients of variability even for the same crop during different years of the experiment are widely apart and thus our results are different from those of Bose [1935], who found that these coefficients were more or less uniform in the three years during which barley, wheat and lentils were successively grown. These conclusions are vividly illustrated in Fig. 7 where the coefficients of variability for the successive crops are represented by horizontal lines drawn at proportionate distances from the base.

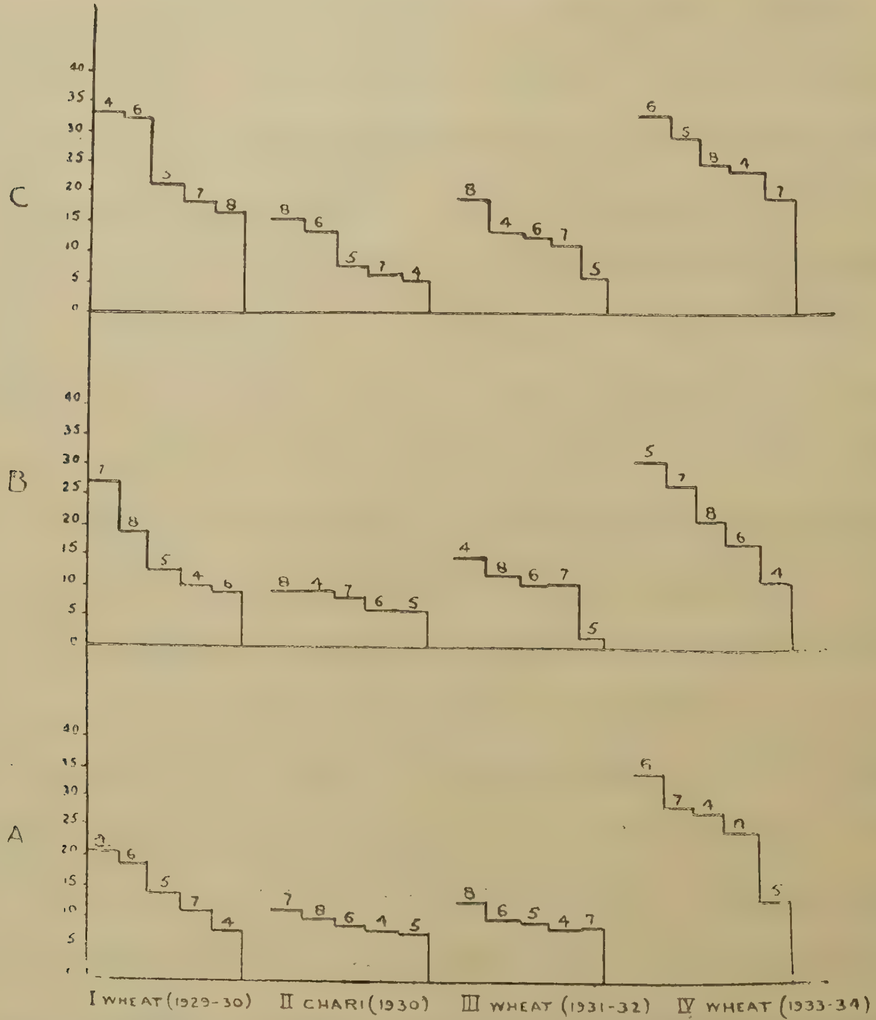


FIG. 7. Coefficients of variability of the four test crops for all the five blocks (4 to 8) in each sub-division, represented by horizontal lines drawn at proportionate distances from the base line

4. (*a*) *Analysis of variance.*—The 'analysis of variance' method as devised by Fisher [1930] aims at dividing the total variation into a number of component parts and thus allows for the elimination of that part of the variance which is due to blocks, this elimination not being possible if the data are considered only from the point of view of the coefficient of variability. Therefore in order to examine the data according to this method, the yields obtained from different plots in sub-division A have been analysed separately, and those from sub-divisions B and C together, considered as one area, have been taken to supply another set of data, since as mentioned already, the object of the experiment in the two cases was different. Sub-division A therefore comprises five randomised blocks of thirteen plots each and sub-divisions B and C taken as one division consist of ten randomised blocks of thirteen plots each. The analyses of variance of the yields for all the four fertility-test crops harvested in different years from the above two areas are given in Table III.

TABLE III

Analyses of variance of plot yields from different crops

Description 1	Mean yield in maunds per acre 2	Source of variation 3	Degrees of freedom 4	Sum of squares 5	Mean square or variance 6	Ratio of variances (x) 7	Coefficient of variability after elimination of block differences 8	Coefficient of variability before elimination of block differences 9
		Sub-division A						
I. Wheat . . .	17·83	Between blocks .	4	1,497·26	374·31	59·89	14·02	29·77
		Within blocks .	60	374·92	6·25	. .	. .	. .
		Total .	64	1,872·18	29·25	. .	. .	. .
II. *Chari* . . .	61·19	Between blocks .	4	2,397·51	599·38	19·92	8·96	13·24
		Within blocks .	60	1,805·23	30·09	. .	. .	. .
		Total .	64	4,202·74	65·66	. .	. .	. .
III. Wheat . .	21·45	Between blocks .	4	2,143·14	535·79	114·50	10·09	28·70
		Within blocks .	60	280·64	4·68	. .	. .	. .
		Total .	64	2,423·78	37·87	. .	. .	. .
IV. Wheat . .	16·00	Between blocks .	4	99·86	24·96	1·37	26·68	26·99
		Within blocks .	60	1,093·47	18·22	. .	. .	. .
		Total .	64	1,193·33	18·65	. .	. .	. .

For $P = 0 \cdot 01$, $n_1 = 4$, $n_2 = 60$, Mahalanobis' $x = 3 \cdot 649$ and for $P = 0 \cdot 05$, $n_1 = 4$, $n_2 = 60$, Mahalanobis' $x = 2 \cdot 525$

Sub-division $(B + C)$

I. Wheat	18·17	Between blocks	9	4,380·66	486·74	31·36	21·68	38·29
		Within blocks	120	1,862·90	15·52	..	..	..
		Total	129	6,243·56	48·40	..	..	..
II. *Chari*	56·75	Between blocks	9	3,026·07	336·23	11·73	9·44	12·49
		Within blocks	120	3,439·37	28·66	..	..	..
		Total	129	6,465·44	50·12	..	..	..
III. Wheat	23·50	Between blocks	9	3,968·65	440·96	43·24	13·59	27·01
		Within blocks	120	1,224·44	10·20	..	..	..
		Total	129	5,193·09	40·26	..	..	..
IV. Wheat	13·16	Between blocks	9	846·64	94·07	9·01	24·56	30·67
		Within blocks	120	1,253·39	10·44	..	..	..
		Total	129	2,100·03	16·28	..	..	..

For $P = 0·01$, $n_1 = 8$, $n_2 = 100$, Mahalanobis' $x = 2·69$ and for $P = 0·05$, $n_1 = 8$, $n_2 = 100$, Mahalanobis' $x = 2·03$

It will be seen from these, that compared with the expected values of x, *i.e.* (v_1/v_2) from Mahalanobis's auxiliary table [1932] the observed values except in the case of the 4th fertility-test crop of wheat in sub-division A which is insignificant even at five per cent point, are highly significant.

Column 8 of Table III gives the coefficient of variability for all the sixty-five plots in sub-division A and 130 plots in sub-division (B+C). The next column gives the figures for this constant before the elimination of block differences.

It will be observed that even after the variation due to blocks has been eliminated, the residual variance in both sub-division A and sub-division B+C is different not only for different crops, wheat and *chari*, but also for the same crop, *viz.*, wheat, in the three different seasons. It will be seen from the figures given in column 6 that inter-block variance, in all cases except one, far exceeds that within the confines of an individual block, thus making the ratio v_1/v_2 highly significant even at one per cent point. This shows that the division of the area into blocks has proved very useful.

4. (*b*) *Analysis of covariance.*—As already shown, the major differences arising from variations of soil fertility can be eliminated to a considerable extent by a careful layout of the area into blocks. Local differences within blocks, *i.e.*, differences between different plots in any one block, however, still remain, and in order to study, as suggested by Sanders [1930], the usefulness of the application of the method of covariance in increasing the precision of the experiment in the case of annual crops, the yields obtained from different plots during the last three years in sub-division A have been corrected by using those of the previous year to represent the natural yielding capacities of the plots. Table IV gives the analysis of covariance for different crops. The variances of the supposed experimental crops (in this case, crops No. II, III, and IV) after correcting the figures on the basis of those for the previous crop have been calculated according to the following formula :—

$$Vyx = Vy - \frac{(Cov \times y)^2}{Vx} \times \frac{60^*}{59}$$

where x and y refer to the preliminary and experimental crop data respectively.

---

* Correction for allowing one degree of freedom for linear regression.

TABLE IV

Analyses of covariance for different crops (sub-division A)

Test crops	Source of variation	Degrees of freedom	xy product	Mean product or covariance
I × II	Between blocks . . .	4	590·65	..
	Within blocks	60	—196·48	—3·275
	Total .	64	394·17	..
II × III	Between blocks . . .	4	1,700·04	..
	Within blocks	60	189·38	3·156
	Total .	64	1,889·42	..
III × IV	Between blocks . . .	4	—86·32	..
	Within blocks	60	—138·30	—2·305
	Total .	64	—224·62	—2·305

The relative precisions for different crops are given in Table V, and it will be seen from the figures there given that there has been no appreciable gain or increase in precision by correcting the yields of the second crop on the basis of the yields of the first, or those of the third or fourth on the basis of the second and third crops, respectively. It will further be seen that the gain in precision in the case of all three crops, slight and inappreciable as it is, is of the same order, which shows that the differences in the seasons or in the kind of crop have in no way increased the degree of accuracy already achieved. The observations of Sanders [1930], who found that a different crop in the preceding year formed a better basis for correction than did the same crop two years before, are interesting to note in this connection. In our case, however, there has been no appreciable gain in precision in the first two cases although in both the crop in the preceding year was a different one. The above conclusions are also borne out by a consideration of the data from Hansi. The data from other stations, which are under examination, also show that the results obtained in any season are not applicable to crops during subsequent seasons. All these data are being examined exhaustively from the point of view of the covariance method and will form the subject matter of a second communication dealing with these trials.

TABLE V

Relative precision of results (sub-division A)

Test crops	Random variance	$V\ y.x$	Relative precision	Percentage gain in precision
Yields of II corrected for those of I	30·09	28·86	1·043	4·3
Yields of III corrected for those of II	4·68	4·42	1·059	5·9
Yields of IV corrected for those of III	18·22	17·37	1·049	4·9

5. Latin square method of examination.—As mentioned already, one of the objects of these trials was to obtain an idea of the 'drift of soil fertility' on the land selected as well as to form an opinion about the suitability for final trials of the form of layout which may be proposed, as a result of the information obtained from soil uniformity trials. We have already seen that, considering the entire area as one piece, the eastern side is more fertile than the western, but how far this fertility varies in a regular manner, either from east to west or from north to south, can best be ascertained if the entire area be treated as a Latin square and the extent of variability both in the direction of the columns and of the rows be measured.

The generally accepted view, that a Latin square may not always be a square and that the plots may be square or rectangular in accordance with the size and shape of the land available, does not hold when it is desired to make a correct comparison between the variation from column to column with that from row to row, because there is an increasing loss in precision as the plots become longer and narrower and thus the comparison will be between two pieces of land which are widely different in size and shape. In order, therefore, to make the basis of comparison as uniform as possible, it is essential that the area should be as nearly a square as possible. With this object in view the entire area was divided into twenty-five plots and the yields adjusted according to the manner explained below. As shown in the layout plan the dimensions of each plot in any one of the blocks are nearly 207 ft. by 19 ft., and each plot is separated from its neighbours in the block by a non-experimental strip five feet wide. Considering the area occupied by these non-experimental strips to be similar to, and a part of, the contiguous plots, the breadth of each separate sub-plot can be taken as 24 ft. Since the yields for each sub-plot have been calculated in maunds per acre, the addition of this five-feet wide non-experimental strip to the width of the plots actually cultivated will make no difference to the relative yields of these different plots assuming that the fertility of these additional five feet is similar to that of the plots on both sides. Eight plots each 24 ft. wide and 207 ft. long will give almost a square. There are, however, only thirty-nine plots in the layout. A fortieth hypothetical plot must therefore be assumed on any one side in continuation of the existing plots. Thus by adding one extra plot to each block of sub-division A towards the south, forty plots are obtained in each field. The yield of this fortieth hypothetical plot may, without introducing any serious error, be assumed to be equal to the mean yield of the corresponding thirteen plots in each block of sub-division A. It may be argued that the yield of this fortieth hypothetical plot could have been arrived at better by the application of the 'missing plot technique'. A moment's reflection will, however, show that this method is not strictly applicable to the case in point. As will be seen from Table III the block differences are significan-in almost all cases. Further examination of the data shows that the 'treatment differences' are insignificant, which, in view of the fact that the treatments were all hypothetical, is as expected. It is clear, therefore, that the yield of the fortieth hypothetical plot, if calculated on the basis of the yields of the plots within all the blocks, is likely to deviate much more from the true yield if the plot actually existed, than it would do, if calculated as a mean of each set of thirteen plots as they exist in each of the five blocks in sub-division A. It could, however, have been arrived at equally well by taking the mean of the seven southern-most plots of sub-division A, since these along with the fortieth hypothetical plot constitute the lowest fifth row in the constituted Latin square. The yield figures for the five plots in the fifth row derived by these two methods are, however, almost identical and the conclusions arrived at by using either figure the same. This was anticipated, because the yields of this fortieth hypothetical plot, by whatever method arrived at, is only one-eighth of the yield of the five plots in the lowest row of the Latin square.

The plots could also be arranged by discarding two plots on either end and dividing the remaining thirty-five plots in combinations of seven plots although in this case the plots within the Latin square will depart to a greater extent from a true square than they did in the former case. This was done and it was found that the conclusions arrived at are the same whether the eight-plot or seven-plot combinations are used.

After treating the entire area as one Latin square (5 × 5), the analyses of the variance of all the four fertility crops are given in Tables VI*a* and VI*b* for the eight and seven-plot combinations respectively.

TABLE VI*a*

Analyses of variance for 5 × 5 combination plots

Source of variation	Degrees of freedom	Sum of squares	Mean square or variance	Ratio of variances (x)		
				Columns and error	Rows and error	Columns and rows
			I. Wheat			
Columns . . .	4	35,770·6	8,942·6	15·84	..	..
Rows . . .	4	10,268·6	2,567·1	..	4·55	3·48
Error . . .	16	9,032·6	564·5	..	..	..
Total .	24	55,071·8	..			
			II. Chari			
Columns . . .	4	24,378·8	6,094·7	4·22	..	..
Rows . . .	4	8,391·6	2,097·9	..	1·45	2·91
Error . . .	16	23,093·6	1,443·4	..	..	..
Total .	24	55,864·0	..			
			III. Wheat			
Columns . . .	4	43,265·0	10,816·2	32·00	..	..
Rows . . .	4	1,774·2	443·5	..	1·31	24·40
Error . . .	16	5,402·2	337·6	..	..	..
Total .	24	50,441·4	..			
			IV. Wheat			
Columns . . .	4	3,684·8	921·2	2·34	..	..
Rows . . .	4	5,039·2	1,259·8	..	3·19	1·37
Error . . .	16	6,310·0	394·4	..	..	..
Total .	24	15,034·0	..			

For $P = 0·01, n_1 = 4, n_2 = 16, x = 4·772$ and for $P = 0·05, n_1 = 4, n_2 = 16, x = 3·007$

For $P = 0·01, n_1 = 4, n_2 = 4, x = 15·978$ and for $P = 0·05, n_1 = 4, n_2 = 4, x = 6·388$

TABLE VI*b*

Analyses of variance for 5 × 5 combination plots

Source of variation	Degrees of freedom	Sum of squares	Mean square or variance	Ratio of variances (x)		
				Columns and error	Rows and error	Columns and rows
			I. Wheat			
Columns . . .	4	30,974·6	7,743·65	23·43	..	..
Rows . . .	4	5,985·8	1,496·45	..	4·53	5·17
Error . . .	16	5,288·6	330·54	..	..	..
Total .	24	42,249·0	..			
			II. Chari			
Columns . . .	4	20,592·6	5,148·15	5·50	..	..
Rows . . .	4	8,876·6	2,219·15	..	2·37	2·32
Error . . .	16	14,967·8	935·49	..	..	..
Total .	24	44,437·0	..			
			III. Wheat			
Columns . . .	4	33,930·0	8,482·50	28·17	..	..
Rows . . .	4	1,080·4	270·10	..	0·90	31·40
Error . . .	16	4,817·6	301·10	..	..	..
Total .	24	39,828·0	..			
			IV. Wheat			
Columns . . .	4	2,829·4	707·35	2·87	..	..
Rows . . .	4	3,899·4	974·85	..	3·96	1·38
Error . . .	16	3,938·6	246·16	..	..	..
Total .	24	10,667·4	..			

For $P = 0·01, n_1 = 4, n_2 = 16, x = 4·772$ and for $P = 0·05, n_1 = 4, n_2 = 16, x = 3·007$

For $P = 0·01, n_1 = 4, n_2 = 4, x = 15·978$ and for $P = 0·05, n_1 = 4, n_2 = 4, x = 6·388$

These show that, except for the fourth crop of wheat (1932-33), the variations in soil fertility are greater from column to column than from row to row. In the case of the first crop of wheat (1929-30), and the second fertility crop of *chari* (*kharif* 1930), this difference although positive is not significant. Thus on the basis of the results of the first two crops we could equally well lay the plots either from north to south or from east to west without any appreciable loss of accuracy. The analysis of the third crop, however, definitely suggests that a considerable gain in precision will result by dividing the area into blocks from east to west and into plots within the blocks also in the same direction. This shows that the layouts as adopted are justified, and the results are in agreement with the conclusions arrived at by Day [1920], Christidis [1931], and others, which state that in order to reduce as far as possible the effects of soil heterogeneity, the plots should be laid lengthwise along the direction of the greater change of soil fertility. In the case of the fourth crop, however, the analysis does not indicate any gain in precision by laying out the plots in either direction. These results again definitely show that an analysis of variance of the yields of one crop cannot be a sufficient guide for deciding the best form of layout of the area into blocks and plots for subsequent experiments on other crops, or even on the same crop in a different season. These conclusions confirm those which have already been arrived at by consideration of the curves and contour diagrams and the coefficients of variability.

If the design of the experiment were based on the results of the previous fertility trials, the best course would be to so divide the area into blocks, that each covers a piece of land which is as uniform as possible in itself, although it may differ widely in fertility from the other blocks. This will eliminate most of the major differences due to soil heterogeneity. The layout of the plots within these blocks should be such that their length runs parallel to the direction of the greater change of soil fertility in each block so that as far as possible each individual plot embraces areas of different grades of fertility.

6. The data obtained from Rawalpindi can also be examined in another manner with a view to obtain information with respect to any particular layout proposed for field trials. It is generally recognised that the greater the number of repeats, the greater the precision of the experiment. However, there are certain workers who are inclined to believe that if the size of the ultimate experimental plots is sufficiently large to include areas of different fertilities, the number of repeats need not be as many as when the plots were of smaller size. The data available from these trials which were conducted on plots as large as 1/11th of an acre can be used to supply information on this point. As already described, the entire area was divided into three sub-divisions A, B and C, each sub-division having five blocks of thirteen plots each. Thus for any treatment there were five replications in each of the three sub-divisions. If, however, sub-divisions A and B or B and C are combined there will be ten replications for each treatment. Similarly taking all three sub-divisions as a whole, there will be fifteen replications. Further, since all treatments during any one season were alike, the mean yields have been calculated from all the 65, 130 or 195 plots in the case of the three sets of replications respectively.

If the size of all the individual plots be kept the same, the area required will vary directly with the number of replicates which it is proposed to study, and unless therefore an additional area, very similar to the previous one, be included for a further number of replicates, it will not be possible to gain any knowledge of the extent to which the precision of the experiment will be increased by increasing the number of replications, since the responses of different grades of soil fertility to variations in seasonal factors are not always the same. With this object in view the variabilities for the four different crops during all the successive seasons have been worked out separately, both for the two different combinations of two sub-divisions each, and for the three sub-divisions considered as one area.

The coefficients of variability for sub-division A, B, and C have already been given in Table II ; these together with other relevant data relating to the three sub-divisions and their combinations are also shown in Table VII. These figures indicate that the coefficient of variability does not show any constancy for the four crops examined in any of the three sub-divisions, although all were raised on the same piece of land and under an identical layout.

TABLE VII

Mean yield, coefficient of variability and the percentage difference required for significance for all the four crops

Sub-divisions and their combinations	Replications	Mean yield				Coefficient of variability				Percentage significant difference at 5 per cent level			
		I Wheat	II *Chari*	III Wheat	IV Wheat	I Wheat	II *Chari*	III Wheat	IV Wheat	I Wheat	II *Chari*	III Wheat	IV Wheat
1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	5	17·83	61·19	21·45	16·00	14·02	8·96	10·09	26·68	17·7	11·3	12·8	33·7
B	5	20·36	59·10	23·89	14·43	14·83	7·80	12·35	22·11	18·8	8·4	15·7	28·0
C	5	15·98	54·39	23·10	11·89	29·17	10·41	14·42	27·59	36·8	13·2	18·3	35·0
A B	10	19·10	60·14	22·67	15·23	14·50	8·41	11·42	24·75	12·9	8·1	9·4	23·6
B C	10	18·17	56·75	23·50	13·16	21·68	9·44	13·59	24·56	19·5	8·4	12·2	21·9
A B C	15	18·06	58·22	22·81	14·10	19·49	9·05	12·50	25·54	14·3	6·6	8·8	18·6

As has been observed previously, in all the three sub-divisions, the second crop, *viz.*, *chari*, showed the least variability, while the last crop of wheat the most. Further, of the three sub-divisions, C showed the greatest variability for all the four crops, the variabilities of A and B being nearly identical. It will be observed, however, that the relative positions of the coefficient of variability for the two sub-divisions alternate during successive seasons. For example, against a coefficient of variability of 14·02 for the first crop in sub-division A we have a slightly greater coefficient of variability for B, *viz.*, 14·83. In the next year with *chari*, however, sub-division A had a higher coefficient of variability than B, and this order was again reversed during each of the two succeeding years. Considering the combinations of the two sub-divisions, A + B and B + C which provide ten repeats each, it is seen that with the exception of the fourth crop where the coefficients of variability are almost the same, the figures for this constant are higher for B + C as compared with A + B, in all the three remaining crops. This is evidently due, in the former case, to the inclusion of sub-division C with a consistently higher coefficient of variability than for the other two. For the same reason, considering all the three sub-divisions as one area, it is seen that the coefficients of variability, except for crop IV (wheat) are higher than those from either A or B separately, although the number of repeats provided is three times as large. Considering the figures given in columns 11 to 14 it will be seen that the differences between treatments required for significance are, in the case of all the four crops, largest for sub-division C. Further, of all the four crops, in any of the sub-divisions or their combinations, *chari* has shown the smallest percentage significant difference. It is clear that except in one case—the first (wheat) crop for B + C — the ten repeats, whether obtained by combining A and B or B and C, as compared with five repeats in any one of the three sub-divisions, have shown a decided improvement in decreasing this difference for all the crops. This decrease becomes more pronounced when we consider the entire area divided into fifteen repeats. Here, except in the case of the first crop (wheat) which shows a difference of 14·3 against 12·9 the corresponding figure for A + B, the remaining three figures are the smallest of all. The higher figures from B + C and A + B + C for the first crop, *viz.*, wheat, are due to the inclusion in these areas of sub-division C, which of all the three sub-divisions showed the maximum percentage significant difference.

The above results clearly indicate that in spite of the heterogeneous nature of the land available, an increase in the number of replications, even though the size of the plot was as large as one eleventh of an acre, has resulted in reducing the percentage significant differences and thus increased the precision of the experiment. It may be concluded from the foregoing discussion that even in large-sized plots there is a regular gain in precision as the number of repeats is increased from five to ten, and from ten to fifteen, the extent of which very largely depends upon the nature of the land used in supplying the additional repeats. It thus appears that the number of replications required to give reliable information will depend upon the nature of the soil, the kind of crop and the climatic conditions under which the trial is conducted.

CONCLUSIONS

The results presented above supply useful information about the value of soil uniformity trials in field work. A number of workers has often recommended the conduct of such trials for evaluating soil heterogeneity and eliminating its effect as far as possible from land on which long-period experiments are to be conducted. Soil heterogeneity has been shown to be a phenomenon of much wider occurrence than is usually realized, and unless it is taken into consideration, the results of field experiments are liable to be misleading. Soil heterogeneity may be roughly classified as casual or superficial and permanent or systematic. The data presented in this paper illustrate both types. It is a common experience of all field experimenters that certain fields exhibit patches or areas which are quite different in their productivity from the remaining portions of the field, and one of the objects is to remove as far as possible the effects of this patchiness. This, however, can be done only in case this patchiness results from casual or superficial causes, such as differences in level or accumulation of soluble plant food materials, etc. If, however, the responsible causes are more or less of a permanent nature, the patchiness whether positive or negative will persist from season to season, irrespective of the crop raised. The magnitude of the difference in yields, however, may vary for different crops. In this case the differential response of these patches can be measured and employed in deciding upon the best form of layout for the area in question. The data relating to trials conducted at Rawalpindi, presented in this paper, supply illustrations of both these types of soil heterogeneity. The permanent type of soil fertility is illustrated very clearly in Fig. 2 from which it will be seen that the fertility of field D_4 for all the crops is above the line of mean yields, while that of D_7 and D_8 is below this line. Consideration of the contours given in Figs. 3-6 shows that the soil fertility varies not only with different crops but even with the same crop in different seasons. This evidently may result from the introduction of superficial factors whose response to seasonal variations may affect the crop yields differently in different years. For example, it will be seen that whereas field D_4 has given consistently higher yields during the four years of these trials, and fields D_7 and D_8 have given lower yields, the yields from fields D_5 and D_6 have varied with different crops due to regions of apparently higher or lower fertility shifting their positions from year to year.

The above general conclusions are supported and amplified by the results of statistical examination of the yield data from these trials. The widely different values for the coefficients of variability (Table II) are a clear indication of the absence of any constancy or uniformity in the fertility of the plots in any of the blocks. This result is different from that of Bose who found these coefficients to be almost uniform in the three years during which barley, wheat and lentils were grown. In the Rawalpindi trials, however, the coefficients differ widely even for the same crop during different years.

As mentioned already the yield data from all the 65 and 130 plots from five to ten blocks in sub-divisions A, and B + C respectively, have also been examined by the 'analysis of variance' method. This eliminates the block differences. As will be seen from Table II the mean plot yields from different blocks in any of the three sub-divisions vary considerably in a number of cases, and therefore the coefficient of variability must necessarily be greater when a number of blocks is considered together than the figure obtained when only one block is considered separately. As a matter of fact, however, it will be seen that the figures given in column 8 of Table III are considerably smaller than those given in column 9. This diminution of the value is due to the elimination of the effects of block differences which constitutes an essential feature of the 'analysis of variance' method.

The 'analysis of covariance' has been recommended by Sanders and others for adjusting the yields of subsequent experimental crops on the basis of the yields from the previous year's crops. In these trials, however, there has been no appreciable gain in precision with any of the three crops, even when the crop used as a basis for this correction was a different one.

The data from Latin square method of layout give a very good indication of the direction in which soil fertility may vary, and this can then be used for deciding the direction in which the blocks as well as plots within the blocks should lie. If, for instance, the fertility increases from north to south, the blocks following the randomised system of layout should be arranged in the same direction, each block covering the entire length of the area from east to west. The plots within the blocks should lie lengthwise from north to south. It is only by such an arrangement that blocks which exhibit maximum fertility differences can be provided, while at the same time individual plots within any block may be as similar in fertility as possible. If, however, the fertility varies systematically both in the direction of columns and rows, the Latin square layout will be preferable. In order to get an idea of the drift of soil fertility of the land selected for field trials at Rawalpindi, the entire area was arranged in the form of a Latin square. It was found that except for the fourth crop of wheat, the variations in soil fertility were greater along the columns than along the rows, although in the case of the first two crops the variation though positive was not significant. The results from the third and the fourth crops, which were different from those of the first and second crops, showed that the analysis of variance of the yields of one crop cannot be used to decide the best form of layout of the area for subsequent trials either with the same or with a different crop.

The above conclusions are also confirmed by the data presented in Table VII. It has been shown that the inclusion of an additional area to provide a larger number of repeats may not always lower the coefficient of variability as calculated from the plot yields. The elimination of block differences does affect favourably the coefficient of variability but in case the additional area included happens to be very heterogeneous, even this may not make a great difference. A consideration of the percentage differences necessary for significance, however, shows that generally speaking the provision of a larger number of repeats results in a gain in precision. The large variations in the percentage significant differences obtained during different years, however indicate that the data from one or two years' trials are not sufficient guide to yield information which could be employed safely for subsequent years. It also suggests that the determination of the best form of layout, or the correct size and shape of the plots for any particular experiment, on the basis of the results obtained from any previous crop whether similar or different from the one to be used in the proposed experiment, has only a limited application.

SUMMARY

1. The yield data from four soil-uniformity test crops grown at the Rawalpindi Agricultural Station have been presented and considered in a number of ways.

2. For the purpose of an uniform basis of comparison the individual plot yields, wherever necessary, have been adjusted by multiplying them by suitable factors so as to give the same average yields for different crops grown in different years, and these results have then been plotted in the form of curves which show at a glance the comparative behaviour of each plot under different crops in different seasons.

3. Fertility contours indicating soil fertility at different places have also been drawn on lines similar to those adopted by the Meteorological Department in representing weather phenomena at various places.

4. The conclusions arrived at from a consideration of these curves and contour maps have been confirmed by the determination of coefficients of variability, and by the analysis of variance.

5. It has been shown that in the case of annual crops the precision of the experiment does not increase appreciably by the application of the method of covariance.

6. The available data have also been examined by considering the entire area as one compact block of twenty-five plots (5 × 5 Latin square). It has been shown that the experimental error can be considerably reduced by adopting suitable methods of layout.

7. Two forms of soil heterogeneity are recognised, *viz.*, casual and permanent. The trials have shown that casual fertility may vary with the crop and season, while permanent fertility is independent of such factors and maintains its level under all conditions.

8. Soil heterogeneity as revealed by any one crop cannot be a true index of the subsequent behaviour of that area with respect to the same or other crops. The value of uniformity trials in deciding the best form of layout for field experiments to be conducted during subsequent seasons is, therefore, limited.

Acknowledgments are due to Malik Sultan Ali, Deputy Director of Agriculture, Rawalpindi, for his kindly conducting these trials at his farm and the supply of necessary data. Our thanks are also due to Bh. Balmokand, Assistant Professor of Physics and Mathematics, for his valuable suggestions and help in the preparation of this paper.

REFERENCES

Bose, R. D. (1935). *Ind. J. Agric. Sci.* **5**, 579

Cheesmann, E. E. and Pound, F. J. (1932). *J. Agric. Sci.* **9**, 277

Christidis, B. J. (1931). *J. Agric. Sci.* **21**, 14

Day, J. M. (1920). *J. Amer. Soc. Agron.* **12**, 100

De Vertenil, J. (1934). *J. Trop. Agric.* **11**, 315

Eden, T. (1931). *J. Agric. Sci.* **21**, 547

Fisher, R. A. (1930). 'Statistical Methods for Research Workers'. Oliver and Boyd, London

Harris, J. A. (1920). *J. Agric. Res.* **19**, 279

——— (1928). *J. Agric. Sci.* **36**, 15

Lander, P. E. (1925). *Agric. Res. Inst. Pusa. Bull. No.* **157**

Mahalanobis, P. C. (1932). *Ind. J. Agric. Sci.* **2**, 686

Murray, R. K. S. (1934). *J. Agric. Sci.* **24**, 177

Sanders, H. G. (1930). *J. Agric. Sci.* **20**, 63

Vaidyanathan, M. (1934). *Ind. J. Agric. Sci.* **4**, 327

——— (1936). *Curr. Sci.* **4**, 457

COMPARISON OF METHODS FOR THE ESTIMATION OF THE FURFURALDEHYDE YIELD OF SOILS AND COMPOSTS

BY

C. N. ACHARYA, M.Sc., Ph.D., A. I. C.

(From the Fermentation Department, Rothamsted Experimental Station, England, and the Department of Biochemistry, Indian Institute of Science, Bangalore)

(Received for publication on 12th October 1937)

I. Introductory

A reference to the literature [Waksman, 1936] on the decomposition of organic matter in soils (*e.g.*, peats and forest soils), composts and manure heaps, would show that the furfuraldehyde yield of such materials, admixed with soil, has been determined by the usual Tollen's procedure [A. O. A. C., 1935] as developed by Kröber [1900]. The applicability or otherwise of this method in presence of soil does not seem to have been subjected to a critical examination.

Various modifications of Kröber's method have been recommended from time to time, both in regard to the procedure for distillation as well as in the method for estimation of furfuraldehyde obtained, but have not so far met with general acceptance.

Powell and Whittaker [1924] suggested a simple method for the estimation of the furfuraldehyde present in the distillate by treating an aliquot of it with a known excess of bromine for one hour and titrating the excess of bromine with standard thiosulphate after the addition of potassium iodide. One molecule of furfural was found to combine with four atoms of bromine under these conditions. Deshpande [1930], Iddles and Robbins [1933], Krishnan [1934], Kline and Acree [1932] and others have reported favourably on the accuracy of Powell and Whittaker's procedure. The advantages of this method are the rapidity with which furfural estimations can be carried out and the lower cost of materials required, as compared with the phloroglucinol procedure. It was, therefore, considered worth while to examine the suitability of this method in presence of soil.

II. Distillation procedure

Some preliminary experiments served to confirm the observations of previous workers that, under controlled conditions, the bromometric method gave results which agreed well with those obtained by phloroglucinol precipitation.

In presence of soil, however, several difficulties cropped up. In the first place, it was found difficult to follow Kröber's procedure of adding 30 c.c. portions of twelve per cent hydrochloric acid once every ten minutes, as it interrupted the boiling and resulted in heavy bumping of the soil material. The distillation, in most cases, could not be continued beyond the second or third addition, and the evolution of furfuraldehyde was irregular and incomplete. The trouble was overcome by keeping 700 c.c. of twelve per cent hydrochloric acid in a conical flask at the boiling point and leading the acid-steam mixture into a 300 c.c. boiling flask containing the soil sample mixed with 100-c.c. of twelve per cent hydrochloric acid. The exit tube from the boiling flask is connected to a condenser and receiver as usual. The distillation is conducted at such a rate that the level of the acid in the boiling flask is maintained at 100 c.c. and 400 c.c. of the distillate are collected in about two and a half hours. Trials with plant materials (without admixture of soil) showed that the procedure gave results closely agreeing with those obtained by the usual distillation method of Kröber.

III. INTERFERENCE OF SOIL IN THE ESTIMATION OF FURFURAL YIELD

The second difficulty met with was the adverse effect which the presence of soil exerted on the yield of furfuraldehyde obtained, as reported already elsewhere [Acharya, 1937]. It was found that plant materials of known furfuraldehyde value gave, when mixed with soil, values which sometimes went as low as fifty to sixty per cent of the correct figure. The degree of interference varied with the nature of the soil, but, for each soil taken separately, was roughly proportional to the amount of soil taken, as will be evident from the figures given in Table I.

TABLE I

Interference of soil in the estimation of furfural yield

Soil added	Furfural yield from 0·4 grm. rice straw					
	Nil	2 grms.	4 grms.	6 grms.	8 grms.	10 grms.
	mg.	mg.	mg.	mg.	mg.	mg.
1. Paddy soil from Aduturai . .	55·2	48·8	42·0	35·4	28·8	21·2
2. Paddy soil from Coimbatore . .	55·2	50·2	45·8	40·4	36·6	31·4
3. Sandy soil from Woburn . .	55·2	54·2	52·6	51·8	50·2	49·4
4. Red soil from Bangalore . .	55·2	52·6	49·6	47·0	44·6	41·8
5. Clayey soil from Bangalore . .	55·2	51·8	49·0	45·4	42·6	39·4

N. B.—The 'control' value for the soil only has been deducted in each case.

It has been observed by previous workers that the presence of tannin and even of lignin adversely affects the furfuraldehyde yield [Sakostschikoff *et al.*, 1934]. With a view to examine whether the interference of soil was due to its organic fraction, five-gram portions of the soils were first ignited and then their effect tested on the furfuraldehyde yield of plant materials. The results, which are given in Table II, show that the harmful effect of soil on furfural yield is increased by previous ignition of the soil sample and hence is not due to the organic matter fraction of the soil.

TABLE II

Influence of ignited soil on furfural recovery

Soil added	Rice straw 0·4 grm.	Wheat straw 0·4 grm.	Barley straw 0·4 grm.
	Furfural yield in mg.		
1. Control value without addition of soil	55·2	69·6	65·4
2. 5 grms. paddy soil from Aduturai .	38·4	52·8	49·2
Ditto ignited . .	32·4	46·2	43·8
3. 5 grms. paddy soil from Coimbatore	43·2	58·2	54·0
Ditto ignited . . .	36·6	52·2	47·6
4. 5 grms. sandy soil from Woburn .	52·2	66·0	62·4
Ditto ignited . . .	45·6	59·4	56·4
5. 5 grms. red soil from Bangalore .	48·4	61·8	58·2
Ditto ignited . . .	44·0	57·2	54·0
6. 5 grms. clayey soil from Bangalore .	47·0	60·2	57·0
Ditto ignited . . .	43·2	56·4	53·2

It was, therefore, considered possible that the low recovery may be due to a portion of the furfural being oxidized by the inorganic constituents present in the soil, *e.g.*, ferric and manganese compounds. An examination showed this supposition to be well founded (Table III). While ferrous and manganous salts have no harmful effect on furfural recovery, ferric and manganic compounds gave low recoveries. The harmful effect of these oxidizing agents on added furfural was much less than on plant materials. This is probably due to the fact that in the case of added furfuraldehyde solutions, the aldehyde was rapidly carried off by the steam and hence there was not much time of contact between the oxidizing agent and the aldehyde; whereas, in the case of plant materials and soil organic matter, furfuraldehyde was only gradually evolved and there was greater scope for the activity of the oxidizing agents.

TABLE III

Influence of oxidizing agents on the recovery of furfuraldehyde

Substance added	Furfural solution	Rice straw 0·5 grm.	5 grms. Aduturai soil and 0·5 grm. rice straw
	Furfuraldehyde yield in mg.		
1. Control value without any addition	60·6	68·4	52·8
2. Ferrous sulphate one grm.	60·2	68·0	52·2
3. Ferric alum, one grm.	58·2	57·0	46·2
4. Ferric chloride, one grm.	56·4	40·2	36·0
5. Ferric oxide, one grm.	55·2	24·0	22·8
6. Manganous chloride, one grm.	60·0	68·0	52·0
7. Manganese dioxide, 0·5 grm.	Nil.	9·0	8·6
8. Sodium nitrate, 1·2 mg.	58·2	65·4	49·2

Kline and Acree [1932] and Bengtsson [1936] have noticed that plant materials give a lower yield of furfuraldehyde in presence of nitrate. The former have recommended its removal by precipitation with 'nitron', while the latter recommends washing the material with water prior to distillation for furfuraldehyde. In the case of soils, however, the high degree of interference noted could only be in a minor degree accounted for by nitrate-nitrogen, since this is usually present only in small quantities in cultivated soils. This was confirmed by the fact that when the soil samples were washed with water, free of nitrate, their capacity for lowering furfural yield showed an actual increase (Table IV).

TABLE IV

	Paddy soil from Aduturai	Paddy soil from Coimbatore
	Mg.	Mg.
1. Furfural value of 0·4 grm. rice straw, without added soil	55·2	55·2
2. Ditto with 5 grms. soil, added without washing	38·4	43·2
3. Ditto added 5 grms. soil, after treating it thrice with 250 c.c. portions of water and stirring for five minutes each time	36·2	41·4
4. Ditto added 5 grms. soil, after boiling the soil thrice with 250 c.c. portions of water for 5 minutes each time	35·4	40·2

The interfering effect is, hence, due mainly to the ferric and manganese compounds in the soil, which, being insoluble, cannot be washed off by water.

It appeared, therefore, that the most effective way to overcome the interfering action of soil was to subject it first to a preliminary reduction, before starting distillation for furfuraldehyde. Various reducing agents were tried for this purpose, *e.g.*, tin and hydrochloric acid, zinc and hydrochloric acid, reduction with Devarda's alloy in alkaline medium, use of zinc-copper couple, etc., but the most effective reducing agent was found to be stannous chloride dissolved in hydrochloric acid. The required amount of stannous chloride (one per cent solution in hydrochloric acid) was added to the flask containing the soil material and the acid-steam distillation was commenced. The added stannous chloride effectively prevented the oxidation of furfuraldehyde and theoretical recoveries were obtained.

IV. COMPARISON OF THE BROMOMETRIC AND PHLOROGLUCINOL METHODS

Having overcome the interfering effect of soil, a detailed comparison of the bromometric (Powell and Whittaker's) and the phloroglucinol methods was undertaken, with a view to examine the possible ill effects of the excess of stannous chloride that may be present in the distillation flask, on the accuracy of the results obtained by the two methods.

Preliminary tests, conducted with 5-grm. portions of different soils to determine the amount of stannous chloride necessary to reduce the ferric and manganese compounds contained in them, showed a great variation between different soils, but for most soils an amount of ten per cent stannous chloride solution equivalent to one c.c. per gram of soil, taken for furfural distillation, was found to be more than sufficient. Experiments were, therefore, conducted to examine the effect of adding increasing quantities of stannous chloride on the recovery of furfuraldehyde by the two methods. The results are shown in Table V.

TABLE V

Influence of the amount of stannous chloride added on the recovery of furfural from soils

Amount of stannous chloride added	Furfuraldehyde yield by		
	Bromine titration method	Phloroglucinol method	
		Before alcohol treatment	After alcohol treatment
	Mg.	Mg.	Mg.
1. Rice straw 0·4 grm. only . .	53·2	52·1	51·8
2. Adutarai soil 5 grms. and 0·4 grm. rice straw, without stannous chloride	35·3	34·7	34·2
3. Ditto 5 c.c. $SnCl_2$ . .	53·6	52·8	52·1
4. Ditto 10 c.c. $SnCl_2$ . .	58·1	52·2	51·0
5. Ditto 15 c.c. $SnCl_2$ . .	62·6	46·4	40·1
6. Ditto 25 c.c. $SnCl_2$ . .	67·2	38·2	26·5
7. Blank with 25 c.c. of $SnCl_2$ without added soil material . . .	Nil	Nil	Nil

It was observed in the course of the experiments that when the amount of stannous chloride added did not very much exceed that which was necessary for the reduction of oxidizing substances present, *i.e.*, when it was of the order of one c.c. per gram of soil taken, the distillate was colourless and the results obtained by the bromometric and phloroglucinol methods agreed well. When the amount of stannous chloride was increased to twice the necessary amount, *viz.*, 2 c.c. per gram of soil taken, the behaviour of the two methods showed marked difference. The distillate acquired a yellowish tinge and the bromine titration value showed a continuous increase, whereas the phloroglucinol value remained at a more or less steady level. On increasing the amount of added stannous chloride above 2 c.c. per gram of soil, the yellowish tint in the distillate became more intense and the bromine value also showed a corresponding increase, but the phloroglucinol value actually decreased.

The difference between the two methods is explainable on the basis that in presence of excess of stannous chloride, methyl-furfuraldehyde is formed from the non-pentose carbohydrates present in the sample [Fenton and Gostling, 1901] (Table VI) and it reacts with bromine similarly to furfuraldehyde, and hence tends to increase the ' apparent furfural ', as determined by the bromine method.

TABLE VI

Influence of stannous chloride on the distillation of non-pentose materials with twelve per cent hydrochloric acid

Added 10 c.c. of 10 per cent $SnCl_2$ and distilled. Control values without $SnCl_2$ were deducted in each case	Apparent furfural yield by		
	Bromine titration method	Phloroglucinol method	
		Before alcohol treatment	After alcohol treatment
	Mg.	Mg.	Mg.
1. Glucose, 1 grm.	48·4	35·3	Nil
2. Soluble starch, 0·5 grm. . .	44·1	33·7	Nil
3. Filter paper, 1 grm. . . .	22·2	15·1	Nil
4. Oat straw cellulose, 0·5 grm. . .	31·4	23·2	Nil
5. Lignin (acid lignin from oat straw) 0·5 grm.	Nil	Nil	Nil

In the case of phloroglucinol precipitation, however (Table V), for the range of stannous chloride from five to ten c.c. per five grams of soil, the amount of methyl-furfuraldehyde formed is apparently small (about 4 to 5 mg. as determined from the increase in bromine value from 5 to 10 c.c. stannous chloride) and, since the phloroglucide of methyl-furfural is appreciably soluble in hydrochloric acid and in the wash water [Fromherz, 1906; Iddles and French, 1936], this small amount is kept in solution and does not add to the total weight of phloroglucide obtained. This is further confirmed by treating the combined phloroglucide precipitates with hot alcohol, which is known to dissolve out the phloroglucide of methyl-furfural [Ellet and Tollens, 1905]. The figures given in Table V show that for the range of five to ten c.c. of stannous chloride, there is very little of methyl-furfural phloroglucide precipitated.

Additions of stannous chloride greater than ten c.c., *i.e.*, greater than 2 c.c. per gram of soil taken, tend to increase the precipitation of methyl-furfural phloroglucide, as shown by the increasing solubility of the phloroglucinol precipitate in alcohol. Further, the high concentration of stannous chloride adversely affects the formation of furfuraldehyde. It is probable that the furfuraldehyde is rapidly converted, under the experimental conditions, into a resistant form, *e.g.*, humin [Hurd and Isenhour, 1932].

It has been mentioned above that within the range of one c.c. to two c.c. stannous chloride added per gram of soil taken, the amount of methyl-furfuraldehyde precipitated by phloroglucinol, under the experimental conditions adopted, was inappreciable. Even the small amount which may be so precipitated could easily be removed by treatment with hot alcohol, and the amount corresponding to furfuraldehyde only can be calculated, applying, of course, a correction for the low solubility of furfural phloroglucide in hot alcohol under similar conditions. Within the above range of stannous chloride, no depressing effect has been observed on the formation of furfuraldehyde. The phloroglucinol method, under these conditions, therefore, offers a procedure for the determination of the true furfuraldehyde yield of soil organic matter.

In the case of the bromometric method, however, there is at present, no satisfactory adaptation of it to deal with mixtures furfuraldehyde and methyl-furfuraldehyde. Hughes and Acree [1937] have recently suggested a modification of the method for this purpose, but the experimental values are open to considerable error and the apparatus and procedure recommended do not commend themselves for routine determinations. Further, as Marshall and Norris [1937] have recently pointed out, there is considerable decomposition of methly-furfuraldehyde during distillation and it is probable that these decomposition products and other volatile products as may be evolved from the original material itself [Sinclair and Bartholomew, 1935] may react with bromine and thus vitiate the value obtained.

It would, therefore, appear that for the estimation of the true furfuraldehyde yield of soil organic matter, the distillation procedure recommended in this paper, using regulated amounts of stannous chloride, followed by precipitation of the furfural with phloroglucinol and subsequent treatment with alcohol, is preferable to Powell and Whittaker's bromometric method.

Typical results obtained by the stannous chloride phloroglucinol procedure with a number of plant materials admixed with soil, are presented in Table VII.

TABLE VII

Values for furfuraldehyde obtained by the stannous chloride phloroglucinol method

Plant material	Control value without soil	5 grms. Adutурai soil		5 grms. Coimbatore soil	
		Without $SnCl_2$	With 5 c.c. $SnCl_2$	Without $SnCl_2$	With 5 c.c. $SnCl_2$
	Mg.	Mg.	Mg.	Mg.	Mg.
1. Rice straw, 0·4 grm. . .	55·2	38·4	55·8	43·2	54·8
2. Wheat straw, 0·4 grm. . .	69·6	52·8	69·0	58·2	70·2
3. Barley straw, 0·4 grm. . .	65·4	49·2	64·8	54·0	65·2
4. Ragi straw, 0·4 grm. . .	73·2	56·0	72·4	60·2	73·6
5. Grass, 0·5 grm. (lawn mowings)	38·4	32·2	38·0	27·0	38·8
6. Bracken leaves, 1·0 grm. .	42·2	25·8	42·8	30·4	41·6

N.B.—Controls for the soils only have been deducted in each case.

V. APPLICATION TO THE ANALYSIS OF COMPOSTS AND OTHER MATERIALS ADMIXED WITH SOIL

The method suggested above is applicable not merely to mineral soils but also to other materials containing soil, *e.g.*, composts, green manures decomposing in the fields, peats, forest soils, etc. The analytical data for the pentosan content of such materials, based on the Kröber procedure, presented by previous workers [Waksman, 1936] would therefore appear to be too low ; the errors may in some cases be of the order of forty to fifty per cent, especially where there is much admixture of soil.

SUMMARY

1. The paper reports a comparison of Powell and Whittaker's bromometric method with the phloroglucinol procedure for the estimation of the total furfuraldehyde yield of soil organic matter.

2. It is shown that the usual Kröber procedure of distillation is inapplicable in presence of soil, on account of excessive bumping, and a method of acid-steam distillation is recommended.

3. The presence of soil seriously interferes in the estimation of furfuraldehyde yield, on account of the oxidizing agents present in the soil, *e.g.*, ferric and manganese compounds, nitrate, etc. The recovery may in some cases go down to forty to fifty per cent of the correct value.

4. A procedure is outlined for removing such interference by the addition of regulated amounts of stannous chloride, before distillation. About one c.c. of ten per cent stannous chloride per gram of soil taken, has been found to be sufficient in most cases.

5. An examination of the bromometric and phloroglucinol methods, under these conditions, showed that correct values could be obtained for soils by the latter method only, since the slight excess of stannous chloride present produces methyl-furfuraldehyde, which increases the value obtained by the bromometric method. In the phloroglucinol method, however, the interference is much less and could be corrected by treatment of the combined phloroglucides with alcohol.

6. The applicability of the stannous chloride phloroglucinol method to the estimation of the true furfuraldehyde yield of composts, green manures, peats, forest soils and other materials admixed with soil or containing interfering oxidizing agents, is indicated.

In conclusion, the writer desires to express his thanks to Sir John Russell and Prof. E. H. Richards of the Rothamsted Experimental Station, England, and to Prof. V. Subrahmanyan of the Indian Institute of Science, Bangalore, for facilities accorded to carry out this investigation.

REFERENCES

Acharya, C. N. (1937). *Current Sci.* **5**, 426

A. O. A. C. (1935). " Official and Tentative Methods of Analysis", 4th Ed., p. 344, Washington D. C., U. S. A.

Bengtsson, N. (1936). *Lantbruks-Högskol. Ann.* **3**, 169

Deshpande, D. D. (1933). *J. Ind. Inst. Sci.* **13A**, 110

Dickson, A. D., Otterson, H. and Link, K. P. (1930). *J. Amer. Chem. Soc.* **52**, 775

Ellet, W. B. and Tollens, B. (1905). *Ber. deut. Chem. Ges.* **38**, 492

Fenton, H. J. H. and Gostling, M. (1901). *J. Chem. Soc. (Lond.) Trans.* **79**, 807

Fromherz, K. (1906). *Z. Physiol. Chem.* **50**, 241

Hughes, E. E. and Acree, S. F. (1937). *Ind. Eng. Chem. Anal. Ed.* **9**, 318

Hurd, C, D. and Isenhour, L. L. (1932). *J. Amer. Chem. Soc.* **54**, 317

Iddles, H. A. and Robbins, P. J. (1933). *Ind. Eng. Chem. Anal. Ed.* **5**, 55

Kline, G. M. and Acree, S. F. (1932). *Bur. Stand. J. Research* **8**, 25

Krishnan, T. S. (1934). *J. Ind. Chem. Soc.* **11**, 651

Kröber, E. (1900). *J. Landw.* **48**, 357 ; **49**, 7

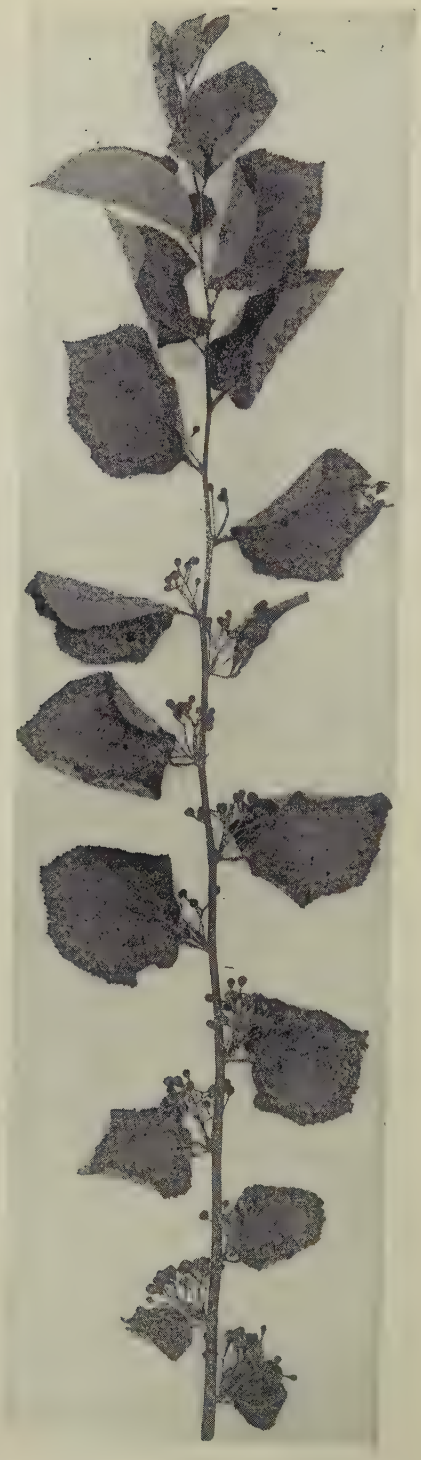
Marshall, C. R. and Norris, F. W. (1937). *Biochem. J.* **31**, 1053, 1289

Powell, W. J. and Whittaker, H. (1924). *J. Soc. Chem. Ind.* **43**, 35T

Sakostschikoff, A. P., Iwonowa, W. T. and Kurennowa, A. M. (1934). *Ind. Eng. Chem. Anal. Ed.* **6**, 205

Sinclair, W. B. and Bartholomew, E. J. (1935). *Amer. J. Bot.* **22**, 829

Waksman, S. A. (1936). " Humus " ; Williams and Wilkins, Baltimore, U. S. A.



A branch of *phalsa* tree showing the position of the fruit

PRUNING OF FRUIT TREES

THE EFFECT OF DORMANT PRUNING ON CROPPING AND VEGETATIVE VIGOUR OF *PHALSA (GREWIA ASIATICA)*

BY

LAL SINGH, B.Sc. (Hons.), M.Sc. (Calif.)
Fruit Specialist, Punjab, Lyallpur

AND

SHAM SINGH, B.Sc. Agri. (Pb.), Ph.D. (Bristol), F.R.H.S.
Assistant Horticulturist

(Received for publication on 6th July 1937)

(With Plates XI-XIII and one text-figure)

CONTENTS

	Pages
I. Introduction	319
II. Material used	320
III. Experimental	322
IV. Presentation of results—	
1. Effect of pruning methods on mean yield per bush	323
2. The effect of pruning on the number of new shoots produced	326
3. Effect of pruning on the size and quality of fruits	326
4. The relation between number of shoots produced and yield as shown by the correlation coefficient	327
V. Discussion and summary of results	328
VI. Acknowledgments	329
References	329
Appendix	330

I. Introduction

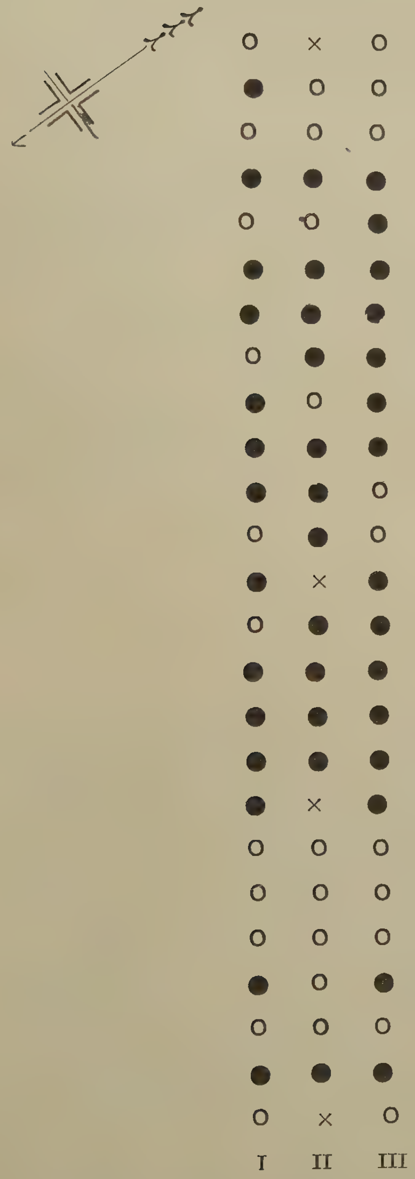
The *phalsa* is indigenous to India [Burns, 1918]. In its wild state it may grow into a tree, but when cultivated it is cut at level with the ground in winter. The new growth, arising out of the dormant buds from below ground and from the little stumps left above ground after pruning, forms the only source of production of fruit. The fruit is borne in clusters in the axil of leaves along the new growing shoots (Plate XI). The method of pruning the whole bush just above ground level, being so simple, is the one that is most commonly employed by *phalsa* growers in the Punjab.

Of late the cultivation of *phalsa* is attracting the attention of fruit growers in this province because it is not so fastidious in its soil, water, manurial and cultural requirements as most other fruit trees are, gives comparatively high returns at an early age and the initial cost of plantation is negligible. The fruit, besides being used in fresh condition, is also greatly relished in the form of '*phalsa* juice' which is becoming one of the most popular summer drinks. The attractiveness of light purple natural colour of *phalsa* drink, its pleasing flavour, and the prevalent belief amongst Indians regarding the medicinal property of its imparting a cooling effect to the system, are the points that find favour with the people at large for the use of *phalsa* juice. As a drink it should favourably compare with, if not actually replace, other summer drinks used in the tropical and sub-tropical parts of the world. Experiments on the preparation of *phalsa* juice and *phalsa* syrup are in progress in the Fruit Products Laboratory at Lyallpur.

So far as the authors are aware, no pruning experiments on this important Indian fruit are recorded in literature. The responses of some other fruit plants to various pruning treatments are discussed at length by Chandler [1932], Knight [1934], Murneek [1933] and Winkler [1929]. It is generally established that heading the fruit plants is essential to the production of new shoots year after year. Gardener, Bradford and Hooker [1927] remark: "Winter heading is much more common with fruits that bear fruit buds on shoots than those that bear them on spurs". Whereas the effects of heading, in general, are well understood, the practical application of the rule must always vary with the kind of fruit and the conditions under which it is grown. It was particularly with this aim that some pruning trials to investigate the effects of various degrees of dormant pruning on the vegetative vigour and fruitfulness of the *phalsa* were laid out in the plantation at Lyallpur.

II. MATERIAL USED

The *phalsa* seedlings growing in the plantation at Lyallpur provided material for these pruning trials. The seedlings were planted in the spring of 1928 at 10 ft. × 10 ft. each way in three rows, and there are twenty-five seedlings in each row. The material was purchased from Government Lawrence Gardens, Lahore, and was raised from seed, which is the most common method of propagating this fruit. Some of the seedlings in all the three rows died during the first year so that only nine to eleven bushes of uniform age and vigour in each row were available for these investigations. Besides, four bushes in row No. 2 were left unpruned from the winter of 1931. The layo t is shown in Fig. 1. All the plants in each row are under one method of pruning except the four bushes marked (× ×) in row No. 2 which were left unpruned. The position of bushes in the plan is shown by circular marks. The shaded circles indicate the position of non-experimental trees and the blank ones denote the bushes under experiment.



Reference :—

○ ○ ○	Experimental bushes
● ● ●	Non-experimental ,,
× × ×	Unpruned ,,
Row I.	Under 'light' pruning
Row II.	,, 'severe' ,,
Row III.	,, 'moderate' ,,

FIG. 1. Lay-out plan of *phalsa* pruning experiment

The methods of pruning tried are illustrated in Plates XII and XIII and may be described as under :—

(*a*) The bushes are cut quite close to the ground (Plate XII, fig. 1) every winter (the general practice with *phalsa* growers). For convenience of reference, this method has been termed 'severe pruning'.

(*b*) The bushes are headed back at a height of about 1½-2 ft. from the ground (Plate XII, fig. 2). By doing this, certain amount of old wood is left above the ground which provides the framework for the bushes on which new growth takes place. The bushes pruned by this method would be termed to have undergone 'moderate pruning'.

(*c*) The bushes are provided still bigger framework by cutting them at a height of 3½-4 ft. from the ground level (Plate XIII, fig. 1), and thereby still further increasing the production of new shoots. This method of pruning has been called 'light pruning'. It may be remarked that in practice one cannot increase the framework to more than four feet because by so doing the fruit will be borne beyond the reach of unaided human hand and its picking would thus be rendered tedious and expensive. It may be mentioned that picking of fruit forms the main item of expense in the cultivation of *phalsa*.

(*d*) The unpruned bushes are shown in Plate XIII, fig. 2. It may be recalled that these bushes were pruned for the first three years after planting, *viz.*, 1928, 1929, 1930, but from 1931 they were left unpruned. This explains why the unpruned plants resemble the light-pruned bushes at the base but the scaffold limbs of 1931 have continued growing with the result that the plants are now unwieldy and most of the crop borne is beyond easy reach of human hand.

III. Experimental

Accurate records regarding cropping and number of shoots produced (indicating vegetative vigour) on each bush have been kept for the last six years (1931-1936) for both experimental and non-experimental bushes. The mean yield and the mean number of new shoots per bush for all the bushes under pruning trials have appeared from time to time in the annual reports of the Fruit Specialist [1935] but the results discussed and the conclusions drawn in the present paper are based on the behaviour of only a certain number of bushes of uniform age shown in the layout plan (Fig. 1). The results of investigations into the effect of pruning are discussed in four sub-heads as under :—

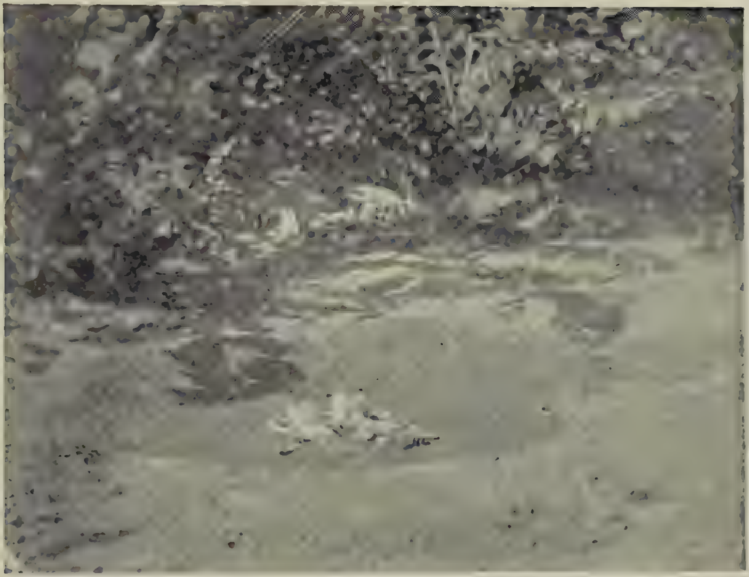


FIG. 1. 'Severe pruning' of *phalsa* bush

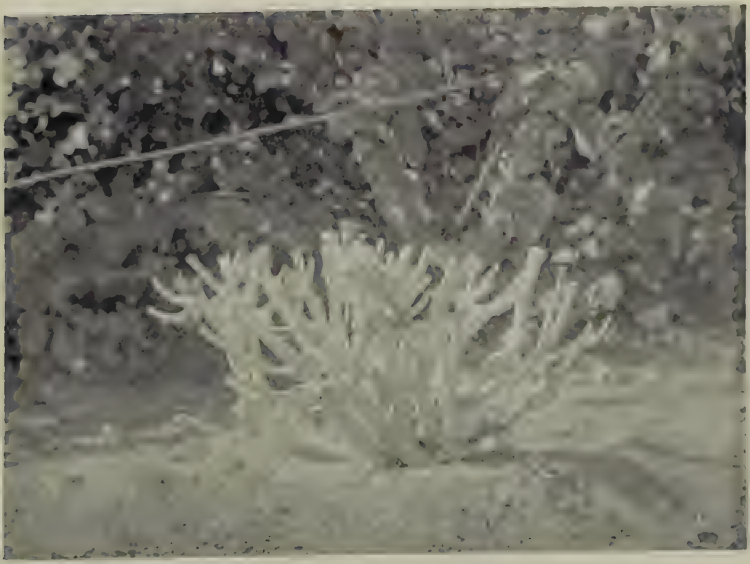


FIG. 2. 'Moderate pruning' of *phalsa* bush

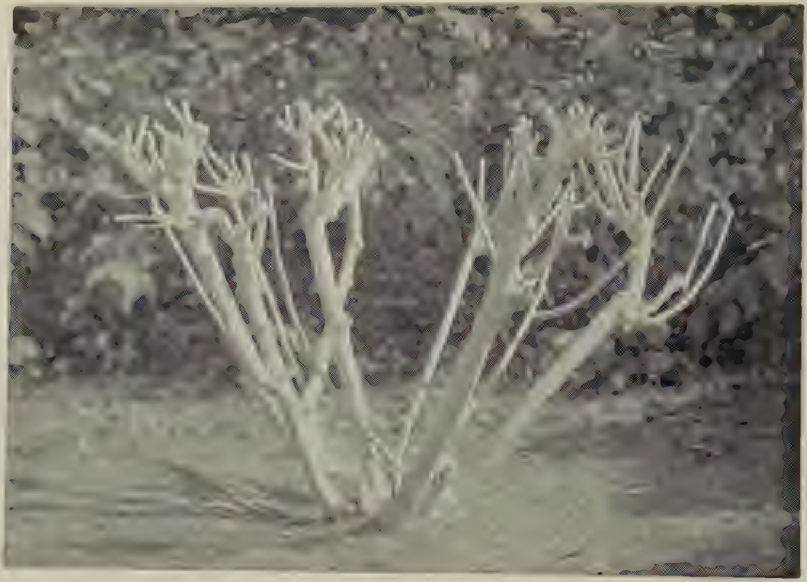


FIG. 1. 'Light pruning' of *phalsa* bush

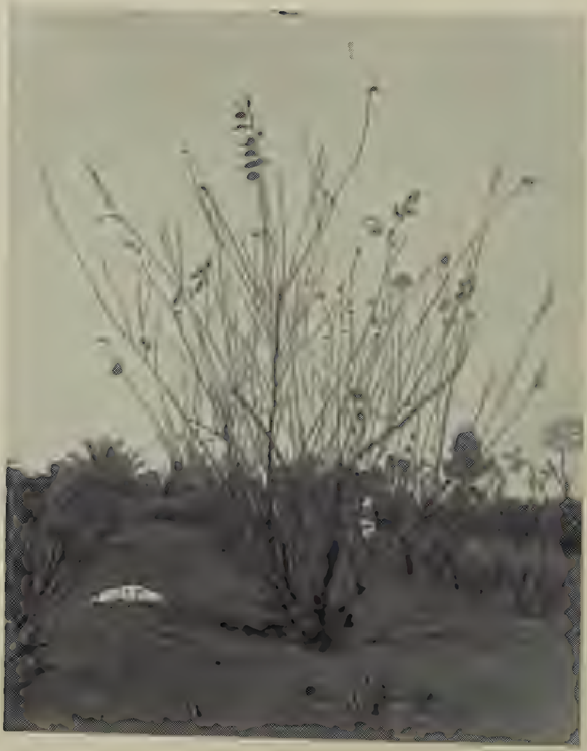


FIG. 2. Unpruned *phalsa* bush

(a) *Yield records*

As would be seen later, the average yield per bush is compared for all the three systems of pruning under trial. The layout being systematic, the mean crop weights per bush can only be compared by '*t*' method after Fisher [1935]. For statistical significance of results, analysis of the crop weight figures for 1936 only is made, and no such examination of the figures for the previous five years (1931-1935) is attempted as the differences are very high and the trend is well in keeping with 1936 figures except on two occasions during 1932 and 1934 for reasons explained in the text.

(b) *Number of shoots per bush*

The number of shoots per bush was counted each year before pruning and records kept. The average number of shoots per bush for each of the pruning treatments could thus be compared amongst themselves. The method of comparison and interpretation is the same as for the crop weights.

(c) *Size of fruit and Balling degree of the juice*

An index to the size of fruit, as affected by pruning methods, is determined by weighing a constant number of 1,000 fruits taken at random from each lot. The Balling degree of the juice is also taken on the same dates when fruit weights were recorded.

(d) *The relation between the number of new shoots and crop weights as shown by the correlation coefficient*

To confirm the general observation, 'the more the number of new shoots the more the fruit', the correlation coefficient has been worked out between the number of new shoots per bush and the amount of crop for the plants under various methods of pruning taken together.

IV. PRESENTATION OF RESULTS

1. *Effect of pruning methods on mean yield per bush*

Table I gives the results for mean yield of fruit per bush in *chataks* (one *chatak* is equivalent roughly to 2 oz.) for the years 1931 to 1936, for the various methods of pruning included in the trial. The yield of individual *phalsa* bushes is, however, given in Table VI (appendix).

TABLE I

Mean crop weight per bush in chataks *for various methods of pruning from 1931 to 1936*

Method of pruning	1931		1932		1933		1934		1935		1936	
	Actual	Per cent	Actual	Per cent	Actual	Per cent	Actual	Per cent	Actual	Per cent	Actual	Per cent
Severe pruning .	33	100	18	100	40	100	15	100	39	100	31	100
Moderate pruning	49	148	16	89	61	153	10	67	71	182	44	142
Light pruning .	74	224	87	483	133	333	45	300	105	269	65	210
Unpruned bushes	68	206	77	428	112	280	38	253	63	162	20	65

It may be mentioned at the outset that hairy caterpillar (*Euproctis* sp.) has been showing appearance in the *phalsa* bushes since the experiment was laid out in 1931. Preventive and remedial measures employed to combat this pest were, as far as possible, uniform for all the bushes. During 1932 and 1934 fruiting seasons, the insect attack was, in general, most severe, particularly in moderately pruned bushes. Although as a result of this, the mean yield per bush was lowered in 1932 and 1934 for all the pruning methods under trial, yet it is interesting to note that even in these years, the light-pruned bushes have given increased outturn over severely pruned bushes to the same extent as during the remaining four years. The outturn of the light-pruned bushes shows an increase of 110 to 233 per cent over the severely pruned bushes. A difference of 383 per cent occurred in 1932, which was an abnormal year. The performance of the moderately pruned bushes was upset during 1932 and 1934, as the bushes gave slightly lower outturn than those pruned to the base, due to localized attack of hairy caterpillar. But in the remaining four normal years the performance was well up to expectations. Thus in 1931, 1933, 1935 and 1936, the moderately pruned bushes have given outturns that are, on the average, forty-two to eighty-two per cent more than those from severely pruned bushes.

The behaviour of unpruned bushes was different from the pruned ones. These bushes have given performance similar to light-pruned bushes during the first three years for reasons stated in the section 'Material used', sub-head (*d*). Later on their outturn per bush is on the decrease in spite of their larger sizes and the higher number of new shoots.

The following generalisations can be made from the data of Table I :—

(*a*) The bushes pruned to the base (severely pruned bushes) have given the least yield except during 1932 and 1934 when they appeared slightly better than moderately pruned bushes due to localized and uneven attack of hairy caterpillar.

(*b*) The bushes cut back 3½ to 4 feet above the ground level (light pruned bushes) have given consistently the best outturns during all the six years of the experiment. The increase in outturn varies, on the average, from 110 per cent to 233 per cent over the widely practised method of pruning the bushes to the base every year.

(*c*) The outturn of unpruned bushes has been gradually falling from year to year although the bushes are largest in size and the number of new shoots is highest. This is probably due to the fact that the shoots on these bushes remain short and slender and are perhaps not able to store sufficient quantities of carbohydrates.

(*d*) The seasonal variations have little or no effect upon the influence of pruning which remains unaffected in extent and degree throughout the period of these trials.

The differences in outturn are very high (110 to 233 per cent) and probably no test for statistical significance is required; however, the mean differences in outturn for 1936 data have been examined statistically. As mentioned before, the layout being systematic, the method of comparing the two means is possible only by '*t*' method after Fisher [1935]. The results are given in Table II.

TABLE II

Phalsa *yield records in* chataks *for 1936*

Method of pruning	No. of bushes under trial	Average yield per bush (*chatak*)	Difference (*chatak*)	S. E. of difference	Value of '*t*' observed	Expected value of *t* for $P = 0{\cdot}05$	
						D. F.	*t*
Severe pruning	9	30·78	12·95	±5·3	2·44	18	2·101
Moderate pruning	11	43·73					
Severe pruning	9	30·78	34·12	±7·25	4·7	17	2·110
Light pruning	10	64·90					
Moderate pruning	11	43·73	21·17	±6·78	3·12	19	2·093
Light pruning	10	64·90					

It will be noticed that moderately pruned bushes as well as light-pruned bushes have given significantly higher yields over the widely adopted method of pruning the bushes to the base every year. The differences of 12·95 ± 5·3 and 34·12 ± 7·25 are highly significant at five per cent points and the latter difference is highly significant even at one per cent point, showing thereby that the odds are considerably more than a hundred to one against such a difference occurring by chance. The difference of 21·17 ± 6·78 is also significant which means that the light-pruned bushes have given significantly increased outturn over those that are only moderately pruned. These figures conclusively show that light-pruning method, *i.e.*, pruning the bushes after leaving a framework of about 3½-4 feet above ground, has proved to be the best under conditions of this experiment.

2. The effect of pruning on the number of new shoots produced

TABLE III

Mean number of shoots per bush for various methods of pruning tried from 1932 to 1936

Method of pruning	1932		1933		1934		1935		1936	
	Actual	Per cent	Actual	Per cent	Actual	Per cent	Actual	Per cent	Actual	Per cent
Severe pruning .	107	100	66	100	99	100	100	100	116	100
Moderate pruning .	230	215	139	211	155	157	174	174	161	139
Light pruning . .	342	319	257	389	239	241	314	314	220	190
Unpruned bushes .	411	384	296	448	538	543	623	623	544	469

Along with the weight of fruit per bush, the number of new shoots was also counted for the last five years from 1932 to 1936 and the results are set out in Table III. As was expected, the bushes pruned severely have the least number of shoots on them; the moderately pruned bushes have greater number of new shoots than those pruned severely; the light-pruned bushes have greater number of new shoots than either of those pruned severely or moderately, and the unpruned bushes have the greatest number of new shoots. This order remains undisturbed for all the five years and these figures are directly related to the crop weight figures of Table I. Thus it appears that the severer the pruning, the less the number of shoots produced. Keeping in view the figures for yield given in Table I, the results of Table III strongly suggest that an increased number of new shoots is followed by increased fruitfulness up to a certain stage only beyond which reverse is the case. This stage appears to have reached, under conditions of the present experiment, in case of bushes cut back at 3½-4 feet above the ground, because no doubt the unpruned bushes have a still greater number of new shoots on them but they remain so short and slender that little fruitfulness results. It may be recalled (Table I) that fruitfulness of the unpruned bushes is diminishing year after years indicating that increased number of shoots is attended by decreased vigour and is followed by decreased fruit-bud formation.

The consistency in the behaviour of the figures in Table III, unaffected as they are by seasonal and other variations, offers an explanation for slight discontinuity in the trend of results for yield during the years 1932 and 1934 which, as stated before, was due to the attack of hairy caterpillar observed in the fruiting seasons of 1932 and 1934.

3. Effect of pruning on the size and quality of fruit

To study the effect of pruning on the size and quality of the fruit gathered from bushes under different methods of pruning, data on the weight of a constant number of fruits taken at random from each set as well as the Balling degree of the juice from those fruits were collected during the ripening season of 1936. Weight of 1,000 fruits was taken in grams on five different occasions during the ripening season and the Balling degree of juice was also taken on the same dates. The data are presented in Table IV.

TABLE IV

Comparison between the mean weight and mean Balling degree of phalsa *fruit obtained from* phalsa *bushes under various methods of pruning*

Method of pruning	Mean weight of 1,000 fruits in grms.		Mean Balling degree
	Actual	Per cent	
Severe pruning	738	100	21·83
Moderate pruning	674	91·3	22·03
Light pruning	528	71·5	24·97
Unpruned bushes	474	64·2	26·07

The figures in column 2 show that the more severe the pruning treatment, the better the size of fruit. The severely pruned bushes, it may be remembered, had the least number of new shoots, followed by least outturn, but the fruits are of the biggest size. It will be seen that as compared with light pruning, the severely pruned bushes lost, on the average, 110-233 per cent in crop weight but gained only by 28·5 per cent in size. It may, however, be mentioned that the growers do not get any premium for the fancy-sized fruit obtained as a result of severe pruning.

The figures in the last column present yet another feature of interest. The size of fruit is no doubt bigger in case of severely and moderately pruned plants, but the quality in both of these sets is far inferior to light-pruned and unpruned bushes. In other words, the increase in the size of fruits is followed by appreciable decrease in quality.

4. *The relation between number of shoots produced and yield as shown by the correlation coefficient*

The relation between number of shoots produced and yield as shown by correlation coefficient is set out in Table V. While working out this correlation, all the bushes (thirty) under different methods of pruning are taken together.

TABLE V

No. of pairs examined	Calculated value of correlation coefficient	Expected value of correlation coefficient for $P = 0·01$	
		n	r
30	0·58	28	0·463

The value of $r = 0·58$ is highly significant by comparing it with the theoretical value of r at one per cent level according to Fisher's tables. This shows that there is a very close association between the number of new shoots and yield. This point is of great practical importance as increased returns can be obtained by inducing more new growth year after year.

V. DISCUSSION AND SUMMARY OF RESULTS

1. The various degrees of dormant pruning tried are (*a*) ' severe pruning ', *i.e.*, cutting the bushes at level with the ground in winter, (*b*) ' moderate pruning ', *i.e.*, heading the bushes at a height of 1½-2 feet above ground and allowing new growth to take place on the framework thus provided, and (*c*) ' light pruning ', *i.e.*, heading the bushes at a height of 3½-4 feet above ground, thus providing a bigger framework than in case of the moderately pruned bushes.

2. The influence of pruning is well marked both for yield and number of new shoots notwithstanding the seasonal variations during the period of six years (1931 to 1936) during which the data were collected.

3. The moderate pruning has proved better over the most widely adopted method of cutting the bushes to the base.

4. The light pruning of bushes, *i.e.*, heading the bushes at 3½-4 ft. above ground, has proved the best of all the methods of pruning here discussed. The differences are found to be highly significant for 1936 data and the trend of results for the previous five years is so much in keeping with these results that their statistical examination seems hardly necessary. The differences, being so high, are conclusive enough to recommend light pruning of *phalsa* bushes in winter.

5. The unpruned bushes form a class of their own and as such give performance quite different from those that were under various methods of pruning. The unpruned bushes are characterised by the greatest number of new shoots produced on them. The increase in the number of new shoots is, however, not followed by increased cropping as most of them remain short and slender. It would, therefore, appear that in order to increase cropping of the *phalsa* bushes, the production of new growths of the desired vigour should be encouraged by heading of old shoots to such an extent as to induce only a certain number of shoots on them.

6. Although even the moderately pruned bushes have given increased production over the severely pruned bushes, yet the optimum relation between length and thickness of new shoots, determined by increased fruitfulness, appears to have best reached in case of light-pruned bushes under conditions of these trials. The concept of this relationship would be better appreciated when the behaviour of the unpruned bushes is considered, because no doubt the unpruned bushes produced a much larger number of new shoots than even the light-pruned bushes, but increased number of shoots is not followed by increased fruitfulness. Actually the outturn is on the decrease year after year. This suggests that new growth of only a certain vigour, determined by the relation of length to thickness, can differentiate fruit buds. That this ideal is best reached in case of light-pruned bushes is substantiated by the data here presented.

7. The size of fruit is directly related to the severity of pruning, *i.e.*, the size of the fruit is much bigger comparatively on severely pruned bushes but the compensation for the gain in size is far less in comparison to the amount of crop lost by severe pruning. Further the increase in the size of fruits is followed by appreciable decrease in quality as indicated by Balling degree of the juice.

8. There is a high positive correlation ($r=0 \cdot 58$) between the number of new shoots and yield in case of the pruned bushes. This relation appears to be most marked in case of light-pruned bushes and has a practical significance in that the new growth of certain vigour only would give the desired performance which can be effected by adopting suitable pruning methods in orchard practice.

9. Other conditions being equal, the severer the pruning in the case of *phalsa* bushes, (*a*) the less the amount of crop, (*b*) the less the number of new shoots and (*c*) the worse the quality of fruit but the greater the size of the fruit.

VI. ACKNOWLEDGMENTS

The authors are indebted to Mr. H. R. Stewart, Director of Agriculture, Punjab, for his kindly providing facilities for carrying out these investigations.

Messrs. Abdul Hamid and Abdul Aziz Khan, Agricultural Assistants, are responsible for the collection of data reported in this paper. Their assistance is thankfully acknowledged.

REFERENCES

Burns, W. (1918). 'Firminger's Manual of Gardening for India', Thacker, Spink & Co., Calcutta

Chandler, W. H. (1932). *Cornell Univ. Bull. No.* **415** (*Ithaca, New York*)

Fisher, R. A. (1935). 'Statistical Methods for Research Workers', (Fifth edition), Oliver and Boyd, London

Gardener, Bradford & Hooker (1927). 'Orcharding', McGraw-Hill Book Company, New York

Knight, R. C. (1934). *J. Pomology and Hort. Sci.* **12**, 1-14

Murneek, A. E. (1933). *Proc. Amer. Soc. Hort. Sci.*, pp. 319-21

Winkler, A. J. (1929). *Hilgardia* **4**, No. 6

Department of Agriculture, Punjab (1935). Summary of Experimental Results for the years 1930-31 to 1934-35. Superintendent, Government Printing Press, Punjab, Lahore

Appendix

TABLE VI

Yield of phalsa *bushes under various methods of pruning for the period 1931 to 1936*

	1931				1932				1933			
	1*	2**	3†	4‡	1	2	3	4	1	2	3	4
	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.
	1 1½	2 8	3 5	3 0	1 ½	0 1½	2 4	3 14	1 12	3 7½	9 1	9 10½
	0 12	2 9	2 13	7 1	1 3	0 14½	3 10	4 2	2 8½	5 3	10 7½	6 4½
	1 15	3 8½	3 3	3 13	0 11½	1 7	7 9	5 13	3 9½	2 6½	8 9	6 0
	1 12	2 15	5 1	3 3½	0 15½	0 13	6 5	5 7	2 9½	4 1½	9 8½	6 2
	2 1½	3 5	6 4		1 3	0 10	5 5		1 13½	3 ½	6 15	
	2 7	1 14½	5 9½		0 14½	1 3	5 4		2 9	3 15	6 4	
	2 10	3 8½	5 8		1 14	0 4	6 8		2 7½	3 13	7 4	
	2 12½	3 8	6 9		1 5½	1 3	6 13		2 15	3 0	11 9¼	
	3 1½	3 15½	4 11½		0 12	0 12½	6 3		2 0	4 2	6 1	
		3 1½	3 5			0 11½	4 6			5 9	7 2	
		2 13½				2 14				3 9½		
Total	18 9	33 11	46 5	17 1½	9 15½	10 14	54 3	19 4	22 4½	42 3½	82 13¼	28 1
Divide by	9	11	10	4	9	11	10	4	9	11	10	4
Average	2 1	3 1	4 10	4 4	1 1⅔	1 0	5 7	4 13	2 8	3 13	8 5	7 0

	1934				1935				1936			
	1	2	3	4	1	2	3	4	1	2	3	4
	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.	Sr. Ch.
	0 11¼	0 10¼	3 6½	1 0	2 ½	1 14	4 7½	2 9	1 15	1 8½	5 9½	1 ½
	1 ½	0 11¼	3 7½	2 6½	2 10½	7 7½	9 7½	4 14	1 15	3 14	4 1	1 6
	0 9¾	0 3¾	1 9	3 14¼	3 6½	3 5½	6 11	5 9	2 7½	3 1½	4 10½	1 4½
	0 8¾	0 1½	0 12½	2 2¾	1 7	6 11½	7 10	2 12½	2 9	3 4	2 11½	1 5½
	2 2½	0 7½	2 ½		1 7½	6 3½	6 13½		0 5½	3 0	3 3½	
	0 14	0 8	2 10		1 13	4 2	4 6		1 12½	3 10	2 7½	
	0 9	1 8¾	4 9¾		2 7½	4 3	5 13		2 8	2 1	5 9	
	0 9½	0 9¾	4 1		3 10	2 11	11 1		2 7	2 8	5 4½	
	1 6¼	0 13¼	4 1		3 3	6 11	5 15		1 4	3 0	3 5½	
		0 10	1 2½			3 9	3 0			2 3	3 7	
		0 3¾				2 1				1 13½		
Total	8 7½	6 7¾	27 12¼	9 7½	22 1½	48 15	65 4½	15 12½	17 3½	29 15½	40 5½	5 ½
Divide by	9	11	10	4	9	11	10	4	9	11	10	4
Average	0 15	0 9½	2 12½	2 6	2 7	4 7	6 8½	3 15	1 15	2 12	4 1	1 4

*1 = Severe pruning.

**2 = Moderate pruning.

†3 = Light pruning.

‡4 = Unpruned bushes

STUDIES ON GROUNDNUT NODULE ORGANISM

I. ISOLATION OF STRAINS AND STUDY OF CULTURES*

BY

T. RAJAGOPALAN, B.A., M.Sc.

Assistant to the Government Agricultural Chemist, Agricultural Research Institute, Coimbatore

(Received for publication on 19th July 1937)

(With one text-figure)

INTRODUCTORY

It has been recognised by practical farmers throughout the world for many generations that the legumes in general have a beneficial effect on the succeeding crops. The actual causes leading to this beneficial effect were not known until the classical researches of Hellriegel and Wilfarth [1888] supported and supplemented by those of Lawes and Gilbert [1889, 1891] and many pioneers in the field, proved beyond doubt the close relationship between the fixation of nitrogen by the plant and the presence of nodules on its roots.

The ancient belief was that the legumes, by their comparatively more extensive root-system than the cereals, were able to assimilate plant food from considerable depths of soil and thus benefitted not only themselves, but also provided necessary food for the succeeding crop. An interesting prediction by Thaer [1856] was that the legumes were capable of taking their food from the atmosphere and improving the soil fertility by depositing therein a portion of the nutrients assimilated through the roots and stubbles. Two years later, Lachmann [1858] pointed out that the nodules of legumes contained bacteria. Subsequently Hellriegel and Wilfarth [1888] sought to connect this bacterial presence with the fixation of nitrogen. Beijerinck [1888] was the first to isolate and grow the organism in a pure state in artificial media. Considerable literature has accumulated since then on the nodule bacteria and a review of the work done on the subject till recently in its various aspects has been presented very lucidly by Fred, Baldwin and McCoy [1932]. Very recently in America and in England, extensive and intensive researches have been carried out to investigate the actual causes and conditions favourable for nitrogen fixation and the effect of inoculation on the yield and quality of the legumes.

It has been proved by a wide distribution of cultures in these two countries that the legumes inoculated with the cultures of certain types or strains of bacteria isolated from their nodules were far superior to the uninoculated ones. The experiments conducted by Thornton [1931] in England on

---

Part of a thesis accepted by the University of Madras for the Degree of Master of Science.

lucerne inoculation started with the aid of grants from the Royal Agricultural Society, have demonstrated the necessity for the supply of efficient cultures to bring about the improvement both in quality and yield of legumes.

As groundnut (*Arachis hypogea*) is one of the most important legumes of great economic importance to the ryots in the Madras Presidency, it is desirable to have a more extended knowledge of the nodule organism associated with the crop, with special reference to its strain variation, and cultural, physiological and biochemical characteristics. The variations in the effectiveness of strains to benefit the host plants were realised even by earlier workers, chief among whom were Lawes and Gilbert [1890, 1891], Nobbe and Hiltner [1893], Déherain and Demoussy [1900] and others. The importance of strain variation in legume inoculation was, however, disregarded for a considerable period and was not recognised till very recently when Stevens [1925] working with *Rhizobium Meliloti* and Wright [1925] with *Rhizobium Japonicum* proved the value of it. These authors besides emphasising the need for selection of efficient strains for inoculation purposes, attempted to group the strains into efficient and inefficient ones based on their cultural and physiological differences. This has since been said to be disputed by the later researches conducted in the laboratories of the University of Wisconsin by Fred and his associates [1932]. A classification of nodule bacteria and their strains has also been effected by serological, immunological and anaphylaxis reaction of the seed proteins by Stevens [1925], Wright [1925] and Baldwin, Fred and Hastings [1927], besides others.

The present investigation reported in this paper was started to find out the variation, if any, in the strains of nodule organism of groundnut in their relative efficiency in fixing nitrogen and to secure first-hand knowledge in regard to their morphological, physiological and biochemical characteristics, with a view to selecting efficient strains by simple and reliable laboratory tests that may be developed as a result of these studies.

EXPERIMENTAL

Six isolates of bacteria were made from nodules of six varieties of groundnut grown in the Oil Seeds Specialist's experimental plots at Coimbatore and Palakuppam and their brief history is given below :—

TABLE I

History of isolates

Isolate number	Variety of groundnut from which isolation was effected	Locality
1	Gudiyattam Bunch . . .	Agricultural Research Station, Palakuppam
2	Hebbal	
3	Local Mauritius . . .	
4	Monte Cassero	Oil Seeds Specialist's experimental plots, Central Farm, Coimbatore
5	Virginia-bunch, Tanganyika .	
6	Spanish-10	

For the isolation of the isolates in pure culture Ashby's yeast-water medium of the following composition was adopted.

Mannite	15·0 grams
Sodium chloride	0·2 gram
Di-basic potassium phosphate	0·5 ,,
Magnesium sulphate	0·2 ,,
Calcium sulphate	0·1 ,,
Calcium carbonate	3·0 ,,
Yeast water	100 c.c.
Distilled water	900 c.c.
Washed agar	15·0 grams
Reaction adjusted to *p*H	7·0

The yeast water used was prepared according to the method of Fred and Davenport [1918] from yeast cells obtained from fermented coconut toddy.

The purity of the cultures was tested by repeated platings on Congo-red yeast-water mannite agar (1 : 40,000 of the dye) and by cultivation on potato slants and litmus milk. The isolates according to these tests were found free from the usual contaminating organism, *Bacillus radiobacter*, and found to belong to the *Pseudomonas* type. Stock cultures of the isolates were prepared and maintained periodically on agar slopes of yeast-water mannite medium described above, for the different experiments.

Testing cultures for nodule production

The cultures of all the isolates were tested for nodule production with all varieties of groundnut from which they were isolated, in sterilised sand with two per cent calcium carbonate and free from nitrogen, following the technique advocated by Thornton [1931] for lucerne inoculation.

Three jars were used for each isolate. The plants, two from each jar, were pulled out at the end of one month and examined for nodules, their size, shape and location, besides noting their general growth and appearance. All the isolates were efficient in producing nodules and the observations made are recorded in Table II.

Cross-inoculation experiments were also conducted with the six isolates on the different varieties of host plants from which they were isolated. All of them were found effective in producing nodules on any of the six varieties of groundnut. Plants from seeds inoculated with isolates 1, 2, 3, and 4 were more vigorous and healthy than with the other two, namely 5 and 6. Regarding the number and location of the nodules also, characteristic differences among the isolates were evident. In the case of isolates, 1, 2, 3, and 4 the nodules were small, greater in number and located mainly on the tap roots, whereas with 5 and 6, the nodules were very big, few in number and situated on the lateral roots.

TABLE II

Degree and nature of nodulation by the six isolates of groundnut nodule organism

Isolate number	Number of replications, jars used	Average growth of plants (total 6)	Number of nodules and their location. Average per plant		Total No. of nodules per plant	Size and shape of nodules
			Main root	Lateral roots		
1	3	Excellent .	12	2	14	Small like mustard and spherical
2	3	Good . .	10	..	10	Size and shape as in 1 above
3	3	Good . .	8	..	8	Do.
4	3	Good . .	6	3	9	Very small like mustard
5	3	Poor and pale .	..	5	5	All very big like pea
6	3	Very poor and pale yellow	..	4	4	Do.

Further isolation of the various isolates was also effected from healthy nodules of plants inoculated with them and they were found morphologically and culturally similar to the original cultures.

Cultural characters

The cultural characteristics of the six isolates were studied in the following media and characteristic differences noted periodically up to three weeks :—

1. Yeast-water-mannite agar.
2. Yeast-water-mannite liquid.
3. Nutrient agar.
4. Nutrient broth.
5. Litmus milk.
6. Citrated milk.
7. Yeast-water-mannite nitrate agar (0·2 per cent KNO_3).
8. Potato.
9. Soil-extract-mannite agar.
10. Groundnut plant extract agar.

All the media except milk and potato were adjusted to pH 7·0. Test-tube cultures were used for the study and the results of the observations made at the end of two weeks are recorded in Table III.

TABLE III

Cultural characters of the six isolates of groundnut nodule organism (Two weeks at 28°C.)

Media	Isolate No.		
	1	2	3
1. Yeast-water-mannite agar	Good growth along the streak, white, dense, margin entire	Good, same as in 1	Good, same as in 1
2. Yeast-water-mannite medium, liquid	Growth good, cloudy and slimy	Same as in 1 . .	Same as in 1
3. Nutrient agar	Poor, flat, slightly raised	Same as in 1 . .	Same as in 1
4. Nutrient broth	Fair, cloudy . .	Fair, slightly cloudy	Fair cloudy
5. Soil-extract-mannite agar	Good along the streak, raised, glistening, white, dense, margin entire	Same as in 1 . .	Same as in 1
6. Yeast-water-mannite nitrate agar	Good, slimy, raised, white and glistening	Same as in 1 . .	Same as in 1
7. Groundnut plant extract agar	Good, raised, white, dense and glistening	Same as in 1 . .	Same as in 1
8. Citrated milk	Good, turbid . .	Same as in 1 . .	Same as in 1
9. Litmus milk .	Good, slightly acid, no serum zone	Same as in 1 . .	Same as in 1
10. Potato . .	Very poor . .	Same as in 1 . .	Same as in 1

TABLE III—*contd.*

Media	Isolate No.		
	4	5	6
1. Yeast-water-mannite agar	Growth good along the streak, raised glistening, white, dense, margin entire	Growth moderate along the streak transparent, slightly raised or flat and thin	Growth moderate to abundant, thin, transparent
2. Yeast-water-mannite medium, liquid	Good, slimy and cloudy	Moderate, less turbid, slimy	Fair, slimy and moderately cloudy
3. Nutrient agar	Poor, same as in 1	Moderate, raised glistening and white	Good, slightly raised, glistening and white
4. Nutrient broth	Fair, cloudy . .	Good, cloudy .	Moderate, cloudy
5. Soil-extract mannite agar	Good, dense, raised white and glistening.	Moderate, transparent, thin or slightly raised	Moderate, transparent, slightly raised
6. Yeast-water-mannite nitrate agar	Good, raised, white, glistening, dense and slimy	Moderate, less dense, slightly raised or thin, transparent and less slimy	Moderate, less abundant, thin, transparent and less slimy
7. Groundnut plant extract agar	Good, raised, white, glistening, dense and slimy	Moderate, thin and transparent	Moderate, slightly raised or flat, thin and transparent
8. Citrated milk.	Good, turbid . .	Moderate, turbid .	Fair, turbid
9. Litmus milk .	Same as in 1 . .	Good, more acidic than 1, no serum zone	Good, more acidic than 1, no serum zone
10. Potato . .	Same as in 1 . .	Very slight growth .	Very slight growth

All the isolates made good growth on yeast-water-mannite agar, with and without nitrate, yeast-water-mannite liquid, citrated milk, soil and plant extract agars. Litmus milk was turned acidic by all the isolates, but the degree of acidity was greater with isolates 5 and 6, than with 1, 2, 3 and 4. The cultures were all slightly alkaline or neutral during the first week and thereafter changed acidic in reaction. In nutrient broth medium, solid and liquid, growth of the isolates 5 and 6 was better than in the others. These differences in the cultural characteristics of the isolates were prominent at the end of two weeks. The variations in the cultural characteristics of the isolates thus tend to divide them into two groups—isolates 1, 2, 3 and 4 constituting group A, and 5 and 6 group B.

Colony characters

Growth of all the isolates on yeast-water-mannite agar plates was rather slow. Well-developed colonies appeared only after a week with isolates 1, 2, 3 and 4 and after five days with the other two. The surface colonies of the first group were all circular, 2 to 3 mm. in diameter, glistening, raised, smooth with margin entire, dense and slimy. The deep colonies were elliptical, lens-shaped with pointed ends, rather white and dull in appearance. The surface colonies of 5 and 6 (group B) were larger—4 to 6 mm. in diameter—flat or slightly raised, watery, less dense and translucent. Except for these differences the isolates were quite similar in other respects.

Morphology of the isolates

All the isolates grown on yeast-water-mannite agar were examined after three days and were more or less similar in size and shape. They all stain, unevenly with the common dyes such as saturated aqueous methylene blue carbol fuchsin, strong and weak (1 : 10), and gentian violet. The staining material segregated in the cells into bands or granules. The size and shape of the isolates three days old varied, however, in general, with the reaction and composition of the medium and also with the strength of the staining solution. The length and breadth of the isolates varied from 2 to 4μ and 0·2 to 0·5μ respectively in the case of rods and with the cocci, the diameter ranged from 0·3 to 0·8μ. The isolates were all Gram-negative when examined at the end of 1, 2, 3 and 5 days. They were all vigorously motile and possessed single flagellum towards the end in a corner. The morphological characters of the isolates being thus very much alike, do not serve to distinguish them one from the other.

Physiology of the isolates

(*1*) *Effect of reaction.*—To test whether there are any differences in minimum and optimum *p*H for the growth of the isolates as well as in the titratable acidity or alkalinity of the cultures, inoculations of the isolates were effected in Buchanan's peptone sucrose medium with reactions varying from *p*H 3·0 to 9·0 at 0·5 intervals. The medium adjusted to different *p*H values was distributed in 10 c.c. quantities in Pyrex test tubes. The reaction of the medium was adjusted electrometrically, on the alkaline side by $N/20$ caustic soda and on the acid side by $N/20$ sulphuric acid. The reaction of the adjusted medium in every case was tested and corrected after sterilisation. Two sets of tubes were used for each culture, one for *p*H and the other for titratable acidity. Determinations of *p*H and titratable acidity of the cultures were made at the end of two weeks. The nature and intensity of growth as revealed by turbidity produced in the medium were also recorded after one and two weeks. Agar streaks were made from tubes where the growths were doubtful and the results checked by observing the growth on the solid medium. The results of observations made at the end of two weeks are recorded in Tables IV and V.

TABLE IV

Change in pH due to the growth of the six isolates of groundnut nodule organism in Buchanan's peptone sucrose medium at different reactions (15 days at 28°C.)

Initial *p*H	Final *p*H and the amount of growth*											
	Isolate 1		Isolate 2		Isolate 3		Isolate 4		Isolate 5		Isolate 6	
	*p*H	Growth	*p*H	Growth	*p*H	Growth	*p*H	Growth	*p*H	Growth	*p*H	Growth
3·5	3·5	—	3·5	—	3·5	—	3·5	—	3·5	—	3·5	—
4·0	4·0	—	4·0	—	4·0	—	4·0	—	4·0	+	4·0	+
4·5	4·4	+	4·4	+	4·5	+	4·5	+	4·1	+	4·0	+
5·0	4·7	++	4·8	++	4·9	+	5·0	++	4·3	+	4·1	++
5·5	5·0	++	5·2	++	5·2	++	5·3	++	4·3	++	4·2	++
6·0	5·5	++	5·5	++	5·6	+++	5·7	+++	4·4	+++	4·3	++
6·5	5·8	+++	6·3	+++	5·8	+++	5·8	+++	4·5	+++	4·5	+++
7·0	6·2	+++	6·5	+++	6·1	+++	6·2	+++	5·8	+++	4·7	+++
7·5	6·3	+++	6·7	+++	6·3	+++	6·3	+++	6·2	+++	6·0	+++
8·0	6·5	++	6·7	+++	6·4	+++	6·5	+++	6·3	+++	6·3	+++
8·5	6·7	++	6·9	++	6·7	++	6·6	++	6·4	+++	6·5	+++
9·0	6·9	+	7·0	+	7·2	++	6·9	++	6·6	++	6·9	+

* —No growth + Fair growth ++ Moderate growth +++ Good growth

TABLE V

Increase in titratable acidity due to the growth of six isolates of groundnut nodule organism in Buchanan's peptone sucrose medium adjusted to different reactions (15 days at 28°C.)

Initial *p*H	Increase in acidity expressed as *N*/10 H_2SO_4 per 100 c.c. of medium					
	Isolate 1	Isolate 2	Isolate 3	Isolate 4	Isolate 5	Isolate 6
3·5 . .	..	..	..	..	..	..
4·0 . .	..	..	..	..	..	..
4·5 . .	..	..	..	..	1·0	1·5
5·0 . .	0·5	1·0	0·5	1·0	2·7	3·0
5·5 . .	1·5	1·7	1·5	3·0	3·5	3·5
6·0 . .	2·7	2·5	2·5	4·5	4·8	3·5
6·5 . .	3·5	3·5	3·2	6·5	5·2	4·0
7·0 . .	6·5	6·7	6·0	8·0	7·0	5·3
7·5 . .	7·2	8·0	6·8	8·4	7·5	6·7
8·0 . .	8·0	8·4	8·2	8·6	8·7	7·2
8·5 . .	7·8	6·2	8·0	8·2	9·0	8·5
9·0 . .	7·0	6·0	7·7	7·9	8·5	8·9

From the tables it may be inferred that there are marked differences both in the critical hydrogen-ion concentration of the various isolates and also in the optimum reaction for their growth. Based on the relative amounts of growth, the changes in *p*H values and titratable acidity in Buchanan's medium adjusted to different reactions, the six isolates can be divided into two groups, namely (*i*) acid resistant and (*ii*) acid sensitive. Isolates 1, 2, 3 and 4 constitute accordingly one group and 5 and 6 the other. The minimum and the optimum *p*H ranges for these two groups are set forth in Table VI. The differences noticed in Buchanan's medium for these two groups of isolates are in harmony with the cultural characteristics noticed previously. These differences indicate, in a way, the physiological differences of the isolates though they were morphologically similar.

TABLE VI

Minimum and optimal p*H values of the six isolates*

Isolate numbers	Minimum *p*H range	Optimal *p*H range
1, 2, 3 and 4	4·0—4·5	6·0—8·0
5 and 6	3·5—4·0	6·5—8·0

(2) *Gum production.*—It is a well-known fact that the legume bacteria produce slime when grown in suitable carbohydrate media. Greig-Smith [1911], Buchanan [1909], Fred [1913] and very recently Hopkins, Peterson and Fred [1930, 1931] have all investigated the nature of the gum produced by the root nodule bacteria of various legumes and the conditions governing its production. The role of the gum produced with regard to nitrogen fixation has not yet been definitely established. An experiment was started with the six isolates to find out the differences, if any, in the amounts of gum produced by them under identical conditions in Buchanan's peptone sucrose medium adjusted to different reactions. At the end of six weeks, the inoculated cultures—two hundred c.c. each—were treated with one and a half volumes of acetone and allowed to settle in the cold for twenty-four hours. The gum precipitated in each case was filtered over a weighed Gooch asbestos filter under suction. It was then washed in several discharges of distilled water and reprecipitated. After three reprecipitations, the precipitate in the Gooch was

weighed, after drying to constant weight at 100°C. in an air oven. The final weights of the gum obtained for the six isolates at different reactions, as well as the critical pH values for their growths, are tabulated in Table VII.

TABLE VII

Gum produced by the six isolates of groundnut nodule organism in Buchanan's peptone sucrose medium adjusted to different reactions. After six weeks at 28°C. Gum dried at 100°C.

Isolate number	Dry weight of gum (100°C.) at different pH values. Mgs. average of two experiments		
	7·8	7·0	6·0
1	169·4	146·6	40·8
2	184·6	161·2	44·6
3	178·6	137·6	39·8
4	168·6	134·6	46·3
5	95·0	69·2	29·2
6	81·8	66·0	27·9

The variations in the amounts of gum produced by the six isolates appear to be related to their cultural characteristics and the optimal hydrogen-ion concentration. The quantities of gum produced by the isolates 1, 2, 3 and 4 are considerably greater than by the isolates 5 and 6. The increase or decrease in the amounts of gum produced varied in general with the profuseness of the growth of the isolates on solid media, especially the yeast-water-mannite agar with and without nitrate. Again, the isolates of group B (5 and 6) with low optimal pH produced less gum than the isolates of group A (1, 2, 3 and 4) with higher optimal hydrogen-ion concentration. There was also a general fall in the amounts of gum produced by the different isolates as the initial pH values of the medium decreased.

Susceptibility of the isolates to dyes

The behaviour of nodule bacteria to basic aniline dyes, especially crystal violet, has been studied by Vandecaveye [1924], Wright [1925], Anderson [1929] and others. As the isolates were all Gram-negative, they should fall within those groups of bacteria which are resistant to aniline dyes. With the object of classifying the six isolates on the basis of the differences shown by their behaviour to crystal violet, Buchanan's peptone sucrose solution at pH 7·0 containing various concentrations of the dye ranging from 1 : 5,000 to 1 : 100,000 was used for the study. Ten c.c. portions from the different concentrations of the dye were distributed in Pyrex test tubes, sterilised and inoculated with the cultures of six isolates at the rate of one c.c. for each tube.

One set of tubes was used for each dilution in the case of all isolates. The tubes were incubated at 28°C. for two weeks and transfers made from them as well as from controls without dyes, on yeast-water-mannitc agar slants. The slant cultures were examined for growth at the end of two weeks and the nature of the growth observed. The results of the observations are recorded in Table VIII. It is evident therefrom that all the isolates were resistant to crystal violet, but with this difference that some grew at lower concentrations than the rest. It has been observed by Fred, Whiting and Hastings [1926] that the cultures withstanding the highest concentrations of the dye, were heavy slime producers. This observation does not seem to hold universally true as it is evident from the present study. For example, isolates 1, 2, 3 and 4 producing more slime than 5 and 6 are less resistant to crystal violet than the other two. The differences noticed in the behaviour of the isolates to crystal violet serve to divide them into two groups—isolates 1, 2, 3 and 4 again constituting one group and 5 and 6 the other. This division supports the classification of the isolates already effected, based on their cultural characteristics, gum production and relation to hydrogen-ion concentration.

Table VIII

Effect of crystal violet on the growth of six isolates of groundnut nodule organism (Two weeks at 28° C.)*

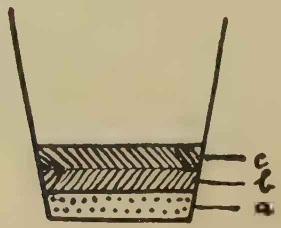
	Isolate number					
	1	2	3	4	5	6
Control	+++	+++	+++	+++	+++	+++
Dilutions of the crystal violet :—						
5,000	—	—	—	—	—	—
7,500	—	—	—	—	—	—
10,000	—	—	—	—	—	+
15,000	—	—	—	—	+	++
20,000	—	—	—	—	++	++
25,000	—	—	—	—	+++	+++
30,000	—	—	—	+	+++	+++
40,000	—	+	+	++	+++	+++
50,000	++	++	++	+++	+++	+++
75,000	+++	+++	+++	+++	+++	+++
100,000	+++	+++	+++	+++	+++	+++

*—No growth. ++Moderate growth

+Slight growth. +++Good growth

Fermentation characteristics of the isolates

One hundred c.c. portions of Ashby's yeast-water medium containing one per cent glucose were used for the study. The cultures after inoculation were incubated for two weeks at 28°C. At the end of the incubation period they were acidified with dilute acetic acid until complete solution of the carbonate in the medium was effected. The final *p*H of the acidified medium was kept between 4·5 and 5·0 for all the isolates lest the cells should be affected. After allowing the cultures to stand for an hour, they were filtered under suction through a specially devised filter illustrated below :—



a. thick felt of asbestos

b. layer of Kieselguhr

c. a layer of fine sand

FIG. 1. Device for filtering cultures

The crucible with its contents was ignited prior to filtration. The filtrate obtained was quite clear showing that the bacterial cells were completely retained. To test positively whether it was so, the filtrate was collected in a sterilised filter-flask under aseptic conditions and a loopful of the filtrate was then inoculated on an yeast-water-mannite agar slant. This slant was examined periodically for any growth over a fortnight. Repeated tests, carried out with the filtrates obtained similarly, revealed the absence of any growth on agar slants and proved the efficiency of the filter in retaining the bacterial cells. The cells retained in the Gooch were then washed a number of times with hot distilled water till free from sugar. The Gooch with the cells was then dried to constant weight at 100°C. in an oven and the weight of the cells synthesised in the medium was obtained by difference between the weights of the filter (dried at 100°C.) before and after filtration. Sugar was determined in the filtrate according to Shaffer and Hartman micro-method as modified by Stiles, Peterson and Fred [1926]. The sugar consumed by the various isolates was obtained by difference between the amounts of sugar found in the beginning and at the end. From the data obtained, the ratio of sugar consumed and the cells synthesised during the given period of incubation was calculated for the six isolates. The cell weight (*c*), the amount of sugar (s) and the $s : ct$ ratio, where t is the period of incubation for each of the six isolates, are given in Table IX.

TABLE IX

Sugar consumed and the cells synthesised by the different isolates in one per cent Ashby's glucose yeast-water medium and the 'ferment power' in 15 days at 28°C.

Isolate number	Dry wt. of cells (100°C.) mgs.	Sugar utilised for the synthesis of cells (mgs.)	Sugar cell ratio s/c	Ferment power ($s : ct$)
	Average of two cultures			
1	52·4	384	7·36	0·489
2	93·6	436	4·66	0·310
3	88·0	417	4·74	0·316
4	83·6	438	5·24	0·349
5	110·0	332	3·02	0·201
6	132·0	473	3·58	0·239

It is obvious from the figures recorded that the $s : ct$ ratios of the isolates differ considerably and they are very low for the isolates 5 and 6. On the basis of these ratios which represent the 'ferment power' of the isolates according to Bonazzi [1921] and others, it is possible to classify them into two groups. According to this division, the isolates, 1, 2, 3 and 4 form one group and 5 and 6 the other. This classification is again in harmony with the division previously effected on the basis of their cultural characters, gum production, behaviour to crystal violet and relation to hydrogen-ion concentration.

Nitrogen-fixation studies

From the previous experiments with the six isolates of bacteria, it is obvious that they were not all of them alike culturally and physiologically and consequently similar differences in their ability to fix nitrogen might also be expected. The information is quite essential, as the ultimate aim of the present study is to produce active cultures of the organism which may be of maximum benefit to the host plant due to increased nitrogen fixation and thereby improving both the yield and quality of the crop. To determine, therefore, the variation in the ability of the isolates with regard to nitrogen fixation two sets of experiments were conducted, one in sand culture free from nitrogen and the other in a garden soil (pH 7·2) with low nitrogen content (0·038 per cent) on a pot-culture scale in the greenhouse on two different occasions. Calcium carbonate (2 per cent) was added both to the sand and soil and thoroughly mixed before distribution in pots. Water, equivalent to fifty per cent of the moisture-holding capacity of each, was further added to all the pots before sterilisation. Three pots were used for each isolate and three were left as controls. Groundnut seeds of uniform size belonging to the Gudiyattam bunch variety were used for sowing. The procedure adopted, in short, for sterilisation and inoculation of the seeds, was that followed by Thornton [1931] for lucerne inoculation. Two seeds were used for each pot and they were weighed out before inoculation to make allowance in the end for nitrogen contained in them. Bryan's modification of Crone's nutrient solution without nitrate, was added to each pot after sterilisation in equal portions of 100 c.c. on different occasions throughout the growing period. Water was also added to the pots in equal lots at different periods, so as to maintain the moisture contents approximately at fifty per cent of the saturation capacities of the sand and soil. The seeds were allowed to germinate in the laboratory and afterwards shifted to the greenhouse where they were kept in cages. The general growth of the plants with regard to their colour, appearance, height, etc., was watched periodically throughout the growing period. The plants from the various pots were pulled out at the end of two months when they were in flowers and pods were just beginning to form. Care was taken to see that no roots were left in the pots. After washing the roots free from sand or soil they were examined for nodules. The samples from the plants inoculated with the six isolates were also analysed individually for total nitrogen by the reduced iron powder method to include nitrates also and the average nitrogen fixed by each isolate was worked out. The dry weights of plants, the number and location of nodules and the nitrogen fixed by the six isolates for the experiment with sand culture are set forth in Table X.

TABLE X

*Pot-culture experiment in sand culture with the six isolates of groundnut nodule organism (April to July 1933)**

Isolate number	Average No. of nodules per plant			Size of nodules	Total dry wt. of 6 plants in gms. from each isolate	Total nitrogen (per cent)	Total nitrogen in 6 plants mg.	Average N per plant in mg.	Average N fixed per plant over control (mg.)
	Main root	Lateral root	Total No. of nodules						
1	25	6	31	Small and medium sized.	14·28	2·17	309·9	51·7	29·1
2	34	10	44	Medium sized, less than pea.	13·21	2·35	310·4	51·7	29·1
3	28	8	36	Small and medium sized.	13·96	2·42	337·8	56·3	33·7
4	34	16	50	Medium sized, less than pea.	15·60	2·31	360·4	60·6	38·0
5	1	15	16	All big like pea . .	12·54	1·98	248·3	41·4	18·8
6	1	5	6	All big like pea . .	10·81	1·90	205·4	34·2	11·6
Control .	...	...	...	......	7·44	1·82	135·4	22·6	...

* Number of pots or replications per isolate, 3,
Total number of plants per isolate, 6,

Characteristic differences were noticed in this experiment between the plants inoculated with group A isolates and those with group B. The plants of group A were taller and more green and vigorous than those of group B. The total yields and nitrogen fixed were also much greater in the case of plants of group A than those of group B. From the table, it is also evident that the roots of the plants have all been infected except for the variations in number, location and size of the nodules. Plants inoculated with group A isolates were full of nodules located in their main roots, whereas in the case of plants from group B, nodules were very few in number but big in size and situated on the lateral roots only.

Results of the experiment using garden soil of *p*H 7·2 and initial nitrogen content of 0·038 per cent are very similar to those obtained in sand, the only noticeable difference being a slight increase in size of nodules.

The grouping of the six isolates into two classes based on their ability to fix nitrogen is, it may be observed, closely correlated with the differences noticed already in their cultural, physiological and biochemical characteristics. It appears from these series of experiments on strain variation, that it may be possible to bring about a division of the different strains of nodule bacteria from a particular host plant or different varieties of host plant into efficient and inefficient ones based entirely on the differences noticed in their cultural, physiological and the biochemical characteristics.

DISCUSSION

The importance of strain variation with regard to nitrogen fixation was recognised and brought to prominence only after the work of Wright [1925] with *Rhizobium Japonicum* and Stevens [1925] with *Rhizobium Meliloti.*

These authors have mainly used the cultural and physiological variations as indicators of effectiveness or otherwise of the *Rhizobia*. The validity of their views has been questioned, as stated by Fred and his collaborators in their monograph on root nodule bacteria [1932]. The present study with the six isolates of groundnut nodule organism was started to find out whether there were any differences in their cultural, physiological and biochemical characteristics and also the existence of any correlation between these differences and their ability to fix nitrogen. The existence of such a correlation has been fully brought out in the present investigation.

The variations in the 'ferment power' or *s* : *ct* ratios of the isolates indicating, as they do, the activity of the viable cells with reference to both nitrogen fixation and carbohydrate utilisation appear to be an easy and reliable test for classifying the isolates into efficient and inefficient ones besides the other usual cultural and physiological characteristics. This classification of the isolates according to the differences noticed in their 'ferment power' does not appear to have been attempted previously and deserves to be investigated further with reference to different types and groups of nodule organism in various carbohydrates media. While it has been observed that the actual amounts of sugar consumed by the various isolates cannot strictly form a basis for evaluating their relative efficiency as nitrogen fixers, the reason for this may not be difficult to seek. It probably depends on the variation of actual amounts of energy liberated by the different isolates due to the decomposition of the carbohydrate. The differences in the amounts of various by-products formed by the two groups of isolates from the crude complex carbohydrates in the nodules and the consequent variations in the energy liberated by them may account, to a large extent, for the differences in the nitrogen fixed by them, when working in symbiosis with the plant. For example, a gram of glucose on complete decomposition will liberate 3·7 calories, *i.e.* when oxidised completely to carbon dioxide and water and 0·19 calorie only when changed to acetic acid alone. The comparatively low amounts of nitrogen fixed by group B isolates in spite of the greater amounts of sugar consumed by them in a given period than those of group A is in all probability due to these differences in the degree and nature of decomposition of the energy material available ; whereas, the increased fixation of nitrogen by the group A isolates is presumably brought about by a more complete oxidation of the carbohydrates, though their quantities may be less, resulting in a comparatively greater liberation of energy than by group B. Thus, the relative efficiency of the two groups of isolates with regard to nitrogen fixation would appear to be a function of their capacity to liberate energy rather than to their ability to utilise sugars, as a result of their biological activities, when the other factors, physical and chemical, such as temperature, composition and concentration of the medium and aeration, are fairly constant.

With regard to the physiological significance of the number, size and distribution of nodule on the plants infected with the six isolates, the results of the present study go to confirm the general opinion of the majority of workers, for instance, Atwater and Woods [1889, 1890], Leonard [1927], Boswell [1929], Thornton [1929] and others, that the health and vigour of the legumes are in a way dependent on these factors. It was also definitely asserted by Dangeard [1926] that the vigour of plant growth is a function of the number of nodules on its roots. Contrary opinion on this point was held by Beijerinck [1918] and Frank [1890] who were of the view that the growth of the plant is dependent more on the development of the nodules rather than on their number. A third school of thought claimed that the location of nodules is the deciding factor so far as their beneficial effect on the plant is concerned. The investigations of Dehérain and Demoussy [1900] with pea and of Hiltner [1902] with lupine have proved that the presence of big-sized nodules on the lateral roots of these legumes are absolutely of no use to the plants. The results of the pot-culture experiments, while disputing Beijerinck's observation, tend to show that the plants stand to benefit if the nodules are situated on their tap roots in great numbers, irrespective of their size, whereas, a fewer and big-sized nodules on the lateral roots are of no use to them. These observations are similar to the findings of Hiltner and others mentioned above. Again Stevens [1925], Baldwin, Fred and Hastings [1927], Thornton [1929] and others have all shown in their work on strain variation of nodule bacteria that the effective strains produce large nodules on the upper parts of the root system, while with the ineffective ones the nodules are generally small and found in greater numbers in the lateral roots. In the present study, the results obtained were rather different.

The nodules of group B, for instance, though located on the lateral roots, were neither small nor greater in number whereas those of group A were small and medium-sized ranging from the size of a pea to that of a mustard, and were all located on the upper parts of the main roots. Löhnis [1930] also, during the course of her investigation on the ineffectiveness of root-nodule bacteria on legumes, observes that the large number of nodules on the lateral roots is not the primary cause of ineffectiveness. Taking all these views and factors into consideration, it appears that the location of nodules, irrespective of size, is the most important of all the factors on which the efficiency or inefficiency of a strain depends.

SUMMARY

1. Isolates of nodule organisms from six varieties of groundnut were compared morphologically and physiologically.

2. The isolates were alike morphologically but fell into two distinct physiological strains.

3. The characteristics of one strain were high gum production, high sensitivity to hydrogen-ions, high 'ferment' power, high nitrogen fixation and production of large numbers of small and medium sized nodules which were concentrated more on the tap-root than on the laterals. The other strain showed the reverse characteristics.

4. The efficiency of the strains as nitrogen fixers appears to depend more on the location of the nodules than on their number and size.

ACKNOWLEDGMENTS

The author wishes to express his deep sense of gratitude to Rao Bahadur B. Viswanath, F.I.C., F.C.S., Director, Imperial Agricultural Research Institute, New Delhi, and formerly Agricultural Chemist to the Government of Madras, and also to Mr. P. D. Karunakar, M.Sc. (U. S. A.), Agricultural Bacteriologist, Agricultural Research Institute, Coimbatore, for their valuable help and advice tendered during the course of this investigation.

REFERENCES

Anderson, I. A. (1929). *Soil Sci.* **28**, 305-313

Atwater, W. O. and Woods, C. D. (1889). *Conn. Agric. Expt. Stn.* (*Storrs*), *Bull.* **5**, 18

——————— (1890). *Conn. Agric. Expt. Stn. Ann. Rept.* (*Storrs*) **2**, 11-51

Baldwin, I. L., Fred, E. B. and Hastings, E. G. (1927). *Bot. Gaz.* **83**, 217-243

Beijerinck, M. W. (1888). *Bot. Ztg.* **46**, 726-735, 741-750, 757-771, 781-790, 797-804

Beijerinck, M. W. (1918). *Proc. Acad. Sci. Amst.* **21**, 183-192

Bonazzi, A. (1921). *J. Bact.* **6**, 331-369

Boswell, V. R. (1929). *Mad. Agric. Expt. Stn. Bull.* **306**, 341-342

Buchanan, R. E. (1909). *Zbl. Bakt.* (*Abt.* **2**) **22**, 371-396

Dangeard, P. A. (1926). *Le Botaniste, Series* **16**, 1-270

Dehérain, P. P. and Demoussy, E. (1900). *C. R. Acad. Sci.* (Paris) **130**, 20-24 ; 465-469

Frank, B. (1890). *Landw. Jb.* **19**, 523-640

Fred, E. B. (1913). *Va. Agric. Expt. Stn. Ann. Rept.* 1911-12, pp. 145-173

Fred, E. B., Baldwin I. L. and McCoy, E. (1932). *University of Wisconsin Studies in Science* **5**, 1-343

Fred, E. B. and Davenport, A. (1918). *J. Agric. Res.* (*U. S. A.*) **14**, 317-336

Fred, E. B., Whiting, A. L. and Hastings E. G. (1926). *Wis. Agric. Expt. Stn. Res. Bull.* **72**, 1-43

Greig-Smith, R. (1911). *Zbl. Bakt.* (*Abt.* **2**) **30**, 552-556

Hellreigel, H. and Wilfarth, H. (1888). *Beilageheft Z. Ver Rubenzucker Ind. Deuts. Reichs.* 1-234

Hiltner, L. (1902). *Dtsch. Landw. Pr.* **29**, 119-120

Hopkins, E. W., Peterson, W. H. and Fred, E. B. (1930). *J. Amer. Chem. Soc.* **52**, 3659-3668

——————————— (1931). *J. Amer. Chem. Soc.* **53**, 306-309

Lachmann, J. (1858). *Landw. Mitt. Z. K. Lehranst. Vers. Sta. Poppelsdorf Bonn.* 1-37

Lawes, J. B. and Gilbert, J. H. (1889). *Phil. Trans.* (*Ser. B*) **180**, 1-107

——————————— (1890). *Proc. Roy. Soc.* **47**, 85-118

——————————— (1891). *J. R. Agric. Soc.* **2**, Ser. 3, 657-702

Leonard, L. T. (1927). *Year-book U. S. Dept. Agric.* 1926, 486-487

Löhnis, M. P. (1930). *Zbl. Bakt.* (*Abt.* **2**) **80**, 342-368

Nobbe, F. and Hiltner, L. (1893). *Landw. Vers. Stn.* **42**, 459-478

Stevens, J. W. (1925). *Soil. Sci.* **20**, 45-66

Stiles, H. R. ; Peterson, W. H. and Fred, E. B. (1926). *J. Bact.* **26**, 427-439

Thaer, A. (1856). 'The Principles of Practical Agriculture ' (*English translation*) by Shaw, W. and Johnson, C., 1-551.

Thornton, H. G. (1929). *J. Agric. Sci.* **19**, 48-70

——————— (1931). *Imp. Bur. Soil. Sci.* (*England*) *Tech. Commun.* **20**, 1-39

Vandecaveye, S. C. (1924). *Wash. Agric. Expt. Stn. Ann. Rept.* **34**, 1-35

Wright, W. H. (1925). *Soil Sci.* **20**, 95-129 ; 130-141

STUDIES ON GROUNDNUT NODULE ORGANISM

II. LIFE-CYCLE OF THE ORGANISM*

BY

T. RAJAGOPALAN, B.A., M.Sc.

Assistant to the Government Agricultural Chemist, Agricultural Research Institute, Coimbatore

(Received for publication on 19th July 1937)

(With Plates XIV and XV)

The existence of morphological variations in the life-history of nodule bacteria has been known from the earliest times and Beijerinck [1888] was probably the first to point out some of the various forms through which the organism passes. Löhnis [1905, 1921], Löhnis and Smith [1916] and Löhnis and Hansen [1921] have all contributed a great deal to settling the dispute regarding the pleomorphic nature of the root nodule bacteria which was the subject of great controversy among the earliest workers. These investigators were able to identify nine different forms of growth from vetch, namely, symplasm, small globules and ovals, small rods and threads with cocci, granular decomposition of the rods, regenerative bodies, budding gonidia, cells with pointed ends and star-like growth. They did not, however, state the conditions under which these stages were obtained.

Bewley and Hutchinson [1920], besides following the regular life-cycle of the nodule organism in culture media, described also the factors responsible for the appearance of the various stages in the development of nodule bacteria (*B. radicicola*). The different stages observed by them were (1) pre-swarmer stage (non-motile coccus), (2) large non-motile coccus, (3) swarmer stage (motile cocci), (4) rod stage (motile) and (5) vacuolated stage (non-motile, banded), ultimately yielding coccoid pre-swarmers. Thornton and Gangulee [1926] followed the life-cycle of the nodule bacteria in soil with reference to the particular stage in which they infect the host plant. Three forms were always observed by them in sterile soil, inoculated with a culture of nodule bacteria, namely, cocci, banded or involution forms and rods. The proportions of these forms were found to vary in different stages of the soil culture. Gangulee [1926], working with *Crotalaria juncea* and *Medicago sativa*, found that the five forms described by Bewley and Hutchinson [1920] were present simultaneously at some stage or other, but the cocci predominated when the conditions were favourable for multiplication. Gibson [1928] has very recently made a thorough study of the life-cycle of the nodule organism and its processes of reproduction. He recognised as many as six stages in the life-history of the organism—rods, coccoids, branched forms, gonidangia, gonidia and dwarfed growth, and microcysts.

---

* Part of a thesis accepted by the University of Madras for the degree of Master of Science.

An investigation was undertaken to find out whether the groundnut nodule organism undergoes pleomorphism in different culture media, both solid and liquid, and passes through the different stages described by Bewley and Hutchinson [1920], Gibson [1928] and others. This study on the morphological variations of the organism is important in so far as it may serve as a clue to its physiological behaviour.

EXPERIMENTAL

Since the isolates were all found morphologically alike, in the preliminary studies (Part I), for the purpose of the present investigation reported in this paper isolate 1 was taken. This isolate was grown under aerobic, anaerobic and partial pressure conditions in a variety of media, liquid and solid, and the growth forms as revealed by the periodical examination of the hanging drops and stained preparations from these cultures were noted. As the organism was found to pass through the same life-cycle at some time or other in all the media, its morphological variations as observed at intervals in Ashby's yeast-water-mannite medium, solid and liquid, are alone recorded in Table I to avoid unnecessary duplication of data.

TABLE I

Morphological variations in the life-cycle of the groundnut nodule organism (isolate 1) in Ashby's yeast-water-mannite medium—solid and liquid—under aerobic, anaerobic and partial pressure (160 mm.) conditions

Nature and condition of the medium	Morphological variations			
	1 day*	3 days	7 days	10 days
1. Yeast-water-mannite agar, aerobic.	Cocci and minute rods.	Short motile rods, cocci and gonidangia.	Cocci and banded rods.	Faintly stained banded rods and motile cocci.
2. Yeast-water-mannite agar, anaerobic.	......	Short motile rods	Short motile rods	Unstained cells and motile rods.
3. Yeast-water-mannite agar, partial pressure (160 mm.).	Banded rods and cocci.	Banded rods, short motile rods and cocci.	Banded and motile rods.	Banded and motile rods.
4. Yeast-water-mannite medium, liquid, aerobic.	Rods and cocci	Motile rods and cocci, gonidangia.	Involution forms and cocci.	Cocci and faintly stained banded rods.
5. Yeast-water-mannite medium, liquid, anaerobic.	......	Faintly stained short banded rods and cocci.	Motile cocci and gonidangia.	Faintly stained motile cocci and banded rods, microcysts.
6. Yeast-water-mannite medium, liquid, partial pressure (160 mm.).	Banded and short rods.	Banded and short motile rods and cocci.	Banded and motile rods.	Banded and motile rods.

TABLE I—*contd.*

Nature and condition of the medium	Morphological variations			
	15 days	22 days	30 days	Growth at 15 days
1. Yeast-water-mannite agar, aerobic.	Banded rods and cocci, liberation of gonidangia.	Banded rods and cocci.	Banded rods and cocci.	Good.
2. Yeast-water-mannite agar, anaerobic.	Faintly stained banded rods, short rods and cocci.	Faintly stained banded rods and cocci.	Faintly stained banded rods, motile rods and cocci, gonidia.	Poor.
3. Yeast-water-mannite agar, partial pressure (160 mm.)	Banded rods and motile cocci, gonidia.	Banded rods and cocci.	Banded rods and cocci.	Good.
4. Yeast-water-mannite medium, liquid, aerobic.	Faintly stained banded rods and small motile cocci, gonidia.	Dwarfed growth, disintegrated banded rods and encapsulated symplasm.	Faintly stained banded rods and cocci, symplasm, regenerative units.	Good.
5. Yeast-water-mannite medium, liquid, anaerobic.	Banded rods and cocci; microcysts germinating.	Banded rods and cocci.	Banded rods and cocci.	Poor.
6. Yeast-water-mannite medium, liquid, partial pressure (160 mm.).	Motile cocci and rods, banded rods and gonidia.	Banded and motile rods, cocci and gonidia.	Small motile cocci and rods, banded rods, gonidia.	Good.

* No trace of growth was visible on the first or the second day on any of the anaerobic cultures.

The media employed for the study were : (1) Ashby's yeast-water-mannite agar, (2) Ashby's yeast-water-mannite agar with 0·2 per cent potassium nitrate, (3) nutrient agar, (4) groundnut plant extract agar, (5) soil extract mannite agar, (6) soil, (7) yeast-water-mannite liquid, (8) yeast-water-mannite without calcium carbonate, (9) yeast-water-mannite without phosphate, (10) yeast-water-mannite with calcium phosphate, (11) soil extract mannite liquid, (12) groundnut plant extract mannite agar, (13) groundnut plant extract mannite liquid, (14) nutrient broth and (15) citrated milk.

These media were prepared in the usual manner and the reaction adjusted to *p*H 7·0 in all cases except the citrated milk and the soil. Stained slides were prepared for the study from dilute suspensions of the various cultures in sterile water using Ziehl's carbol fuchsin and other dyes tried by Gibson [1928]. Erythrosin dye recommended by Gangulee [1926] was adopted for following the various stages in the life-cycle of the organism in soil, but it did not give satisfactory results, as the organism was too poorly stained for a detailed examination under the microscope.

Aerobic cultures

(*a*) *Solid media.*—The organism made a fairly good growth in all the media tried. The growth in nutrient agar was only moderate and poorer than in the others, especially groundnut plant extract, soil extract and yeast-water-mannite media. The size and shape of the organism varied with the medium and the difference was more evident in nutrient agar, wherein the organism was considerably smaller, especially the rods in the earlier stages, than in the other media. It may be seen from Table I that the organism passed through almost all the stages described by Bewley and Hutchinson [1920] and Gibson [1928]. The rods and cocci of the motile type were found generally in the earlier stages in all the media up to ten days and afterwards the rods became enlarged with bands inside. In mannite soil extract and Ashby's mineral medium the cells were stained faintly and remained static in that state for a long period. The organism attained the banded rod stage in these media between the seventh and tenth day and subsequently reproduction followed resulting in the emergence of the vigorously motile cocci. A third stage in the life-cycle of the organism was the appearance again of the banded rods and cocci with no motility. This final stage was reached normally within three to four weeks in these media. In nutrient agar similar phenomena were observed but the degree and duration of reproduction after the first banded rod stage was reached were greater than in the other media, though it was not a favourable medium for a profuse growth of the organism. Spherical, well-stained gonidangia in the form of cyst-like growths were also noticed in the earlier stages in almost all the solid media after five days.

(*b*) *Liquid media.*—In liquid media also, the organism passed through all the stages as in the solid media. The motile stage appeared in all the cultures only after twenty-four hours. Growth was very poor in the medium without phosphate. Motility was very vigorous in nutrient broth and groundnut plant extract media throughout the whole period of observation. In the case of other liquid cultures it continued for about a week, when the banded rod stage was reached, and subsequently reproduction commenced as in solid media. This secondary stage continued for another week and thereafter remained stationary up to the entire period of observation. In groundnut plant extract, the growth was very vigorous. Thread-like forms with series of segments and granules inside were also found and scattered round them were present small rods and cocci. The banded rod stage appeared in this medium at the end of three weeks. Gonidangia in the form of cyst-like large cells containing a number of granules which subsequently on liberation became gonidia were also present in numbers in the plant extract medium.

Anaerobic cultures

Solid and liquid media.—Eight tubes were used for each medium and one tube was taken on every occasion when the examination was made. The tubes were placed in Buchner tubes containing alkaline pyrogallol, completely sealed with paraffin and incubated at 28° C. When once a culture was opened and examined, it was discarded to avoid the disturbances that might be set up due to intermittent admittance of air. The growth of the organism in all the media was very poor. Practically all the main stages of Bewley and Hutchinson [1920] were observed in all the media under anaerobic conditions, though the growth of the organism was extremely meagre. Oxygen is obviously the limiting factor for the normal growth of the organism. In solid and

LIFE-CYCLE OF THE GROUNDNUT NODULE ORGANISM

(Magnification ×1000 in each case—stained with aqueous carbol fuchsin)

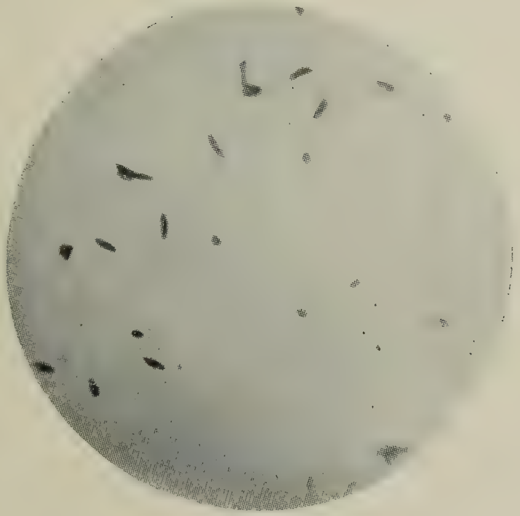


Fig. 1. Yeast-water-mannite medium, aerobe, one day, rods and cocci

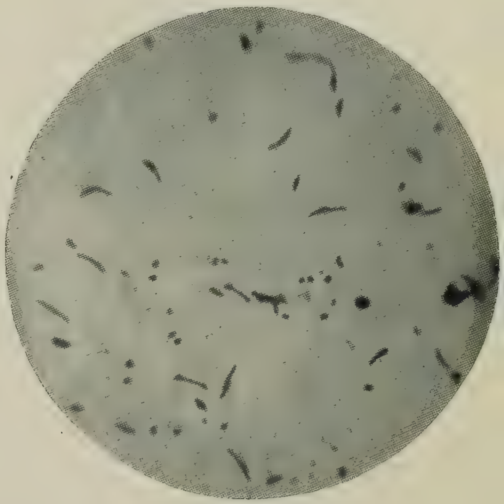


Fig. 2. Yeast-water-mannite medium, aerobe, seven days, involution forms and cocci

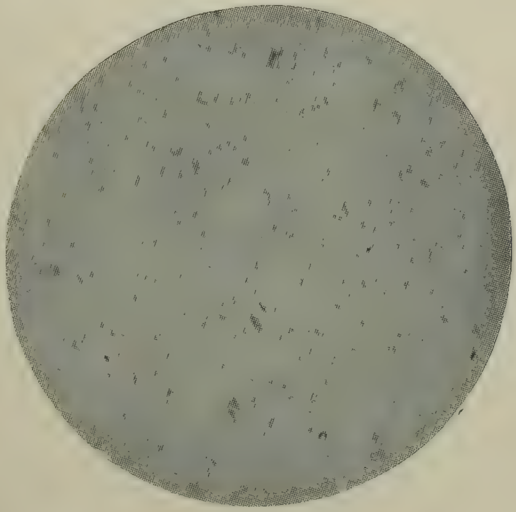


Fig. 3. Yeast-water-mannite medium, aerobe, ten days, faintly-stained, small banded rods and cocci

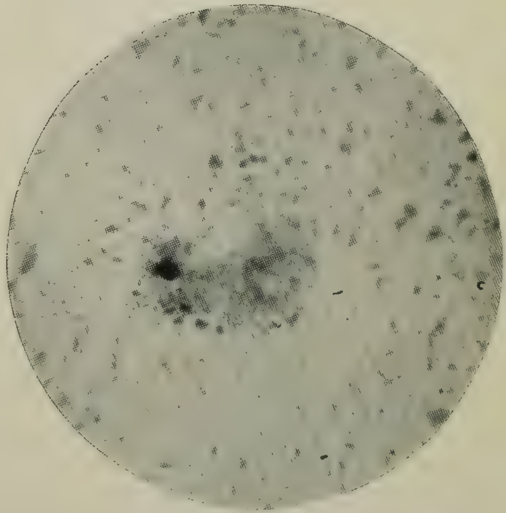


Fig. 4. Yeast-water-mannite medium, aerobe, twenty-two days, dwarfed growth and encapsulated symplasm

LIFE-CYCLE OF THE GROUNDNUT NODULE ORGANISM

(Magnification ×1000 in each case—stained with aqueous carbol fuchsin)

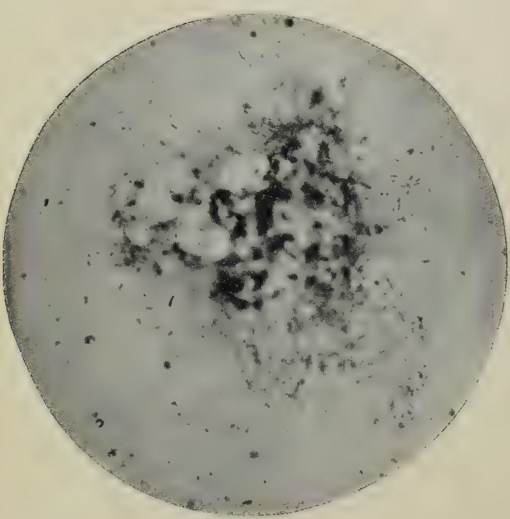


FIG. 1. Yeast-water-mannite medium, aerobe, thirty days, symplasm, formation of regenerative bodies, rods and coccoids

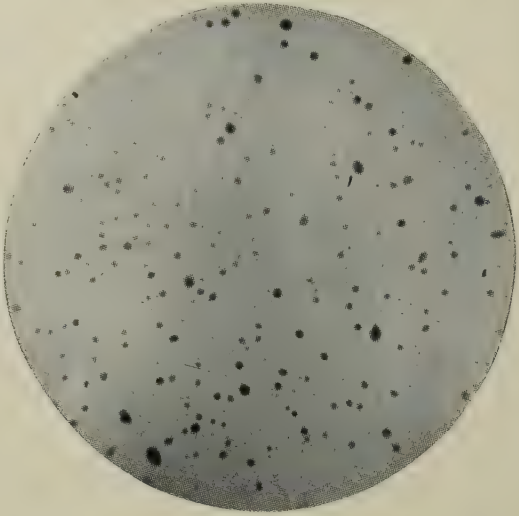


Fig. 2. Yeast-water-mannite medium, anaerobe, seven days, granulated cocci and gonidangia

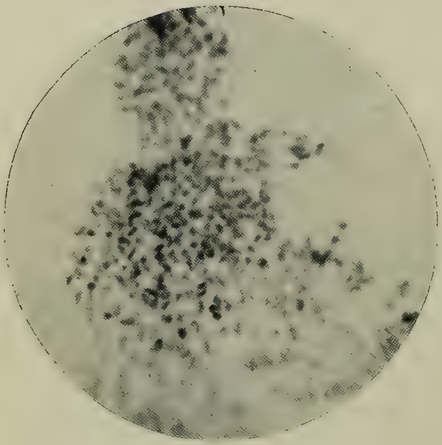


FIG. 3. Yeast-water-mannite medium, anaerobe, ten days, microcysts in clumps

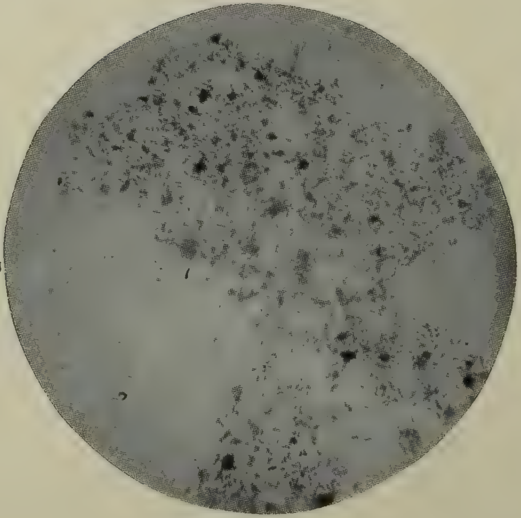


FIG. 4. Yeast-water-mannite medium, anaerobe, fifteen days, microcysts germinating

liquid media, banded rod stage is reached within fifteen days and reproduction commenced afterwards as in the aerobic cultures. In solid agar media and in nutrient broth the motile forms were noticed almost throughout the period of observation which continued over thirty days, whereas with the other liquid media, the resting period corresponding to the involution or the banded rod stage was more prolonged. In general, the banded rods were more prominent in all the media under anaerobic conditions.

Partial pressure cultures

The inoculated tubes in duplicate were placed within Bullock's apparatus and the air inside exhausted partially under a pump till the pressure reached 160 mm. per sq. cm. One set of tubes was taken out every time the observation was made and replaced immediately after the cultures were removed for examination. The air inside the apparatus was partially exhausted till the original 160 mm. pressure was reached. This procedure was repeated on every occasion the cultures were taken out for examination. In yeast-water-mannite medium, liquid and solid, banded rod stage was visible even within three days. Motility ceased before ten days in these media and reproduction ensued thereafter as in the case of aerobic cultures with the production of pre-swarmers and swarmers of vigorous motility. The swarmer stage continued for less than a week in the yeast-water-mannite agar medium and it was followed by the appearance of banded rods and cocci with no motility. In the nutrient agar, the banded rod stage was observed on the tenth day and motility was completely absent in the medium at this stage. Subsequently, reproduction occurred with the production of motile cocci and rods which persisted throughout the entire period of observation up to thirty days. The banded rod stage was, in general, predominant in all the media from the tenth day onwards. In the broth medium, besides the usual stages observed in the other media, thread-like growth was evident from the seventh day onwards. The motility of the organism, rods and cocci, continued throughout the whole period of the experiment in this medium.

Aerobic culture

Soil.—A loopful of the distilled water suspension of the inoculated soil from a flask was taken periodically and examined for the various forms of the bacterium both alive and stained. In this medium the proportion of cocci to other forms was found to decrease with the time of incubation. The technique adopted for staining the organism was that of Gangulee [1926] The organism is distinguished from the soil particles by their pink colour. Though the contrast was evident, the organism was very faintly stained and difficulty was experienced in examining them in detail. Application of heat or prolonging the period of staining did not improve matters.

Photomicrographs of some of the typical forms of the organism observed in a selected culture, namely, Ashby's yeast-water-mannite medium, liquid, are reproduced in Plates XIV and XV. Owing to poor staining of the organism by aqueous carbol fuchsin, due probably to the slime produced in the culture, details of the bacterium could not be reproduced well in some of the photographs presented. Substitution of dyes other than carbol fuchsin did not, however, improve matters.

Discussion

As a result of the observations made during the course of this investigation, it may be said in general that the groundnut nodule organism passes through the five stages of Bewley and Hutchinson [1920], namely, pre-swarmer non-motile coccus, pre-swarmer large motile coccus, swarmer stage, motile coccus, rod stage (motile) and vacuolated stage in all the media including soil under aerobic, anaerobic and partial pressure conditions. These stages occur in most cases simultaneously but in varying proportions. The size and shape of the cells vary according to the nature of the medium in which the organism is grown and the differences noticed are the greatest in the nutrient broth media, solid and liquid. The reproductive processes of the organism appear to take place mainly by (1) budding of cells and rods with terminal ends, (2) liberation of gonidia from banded rods and cyst-like gonidangia and (3) germination from filaments and microcysts, *e.g.*, on groundnut plant extract and mannite-yeast-water media. The nature and composition of the culture influence also the type of development of the organism. For instance, the thread-like growth and gonidangia, frequently met with in groundnut plant extract medium, were very rarely found in other cultures. The existence of gonidia in the banded rods and large spherical cells, observed in most of the cultures, especially under aerobic conditions, was also recognised by earlier writers and these were called swarmers. Beijerinck [1888] found this gonidia possessed of single polar flagellum before the gonidium itself became free from its mother rod. Similar observations were also recorded by Löhnis and Hansen [1921]. It may be seen also from the present study that in almost all the media, after the organism had attained the banded rod stage corresponding to the first resting stage, vigorous motility occurred, due probably to the direct liberation of swarmers in the form of motile cocci. It appears therefore that the pre-swarmer of Bewley and Hutchinson [1920] is not a necessary stage in the life-cycle of the organism. This observation is in agreement with that of Gangulee [1926] in connection with his studies on lucerne nodule organism. The characteristic of gonidia or swarmers liberated directly from the banded rods is their extremely vigorous motility which is distinct from the comparatively slow movement of the rods. Again, the appearance of the banded or involution form in the life-cycle of the organism in different media has often been associated with the death or katabolic processes of the organism. That this change observed is not pathological is evident from the reproductive processes noticed in the various media after the organism has reached the banded or involution stage. The so-called involution form would appear from the present study and also from the investigations of Gibson [1928] and others, to be one of the normal stages in the development of the organism.

SUMMARY

1. The life-cycle of a selected strain of groundnut nodule organism was studied in different media including soil under varied conditions and the different processes of reproduction observed are indicated.

2. The organism passed through the different stages described by Bewley and Hutchinson, Gibson and others, namely, rods, coccoids (motile and non-motile), gonidangia, gonidia and microcysts. The results of the observation also show that the motile cocci or the swarmers could emerge directly from the banded rods without passing through the non-motile pre-swarmer stage.

3. The reproduction observed in almost all the media, after the banded rod stage was attained, indicates that the so-called involution or banded rod stage represents one of the normal processes in the development of the organism.

4. The reproductive processes of the organism seem to take place in the main by budding, germination, liberation of gonidia and by formation of regenerative units from symplastic stage.

5. Under anaerobic conditions, the banded rods were noticed in abundance in all the media and the motility was more persistent in solid media and in nutrient broth than in other cultures.

6. In the partial pressure cultures also, the banded rod stage was predominant throughout the entire period of observation in almost all the media tried, except nutrient broth media, solid and liquid, wherein this stage appeared and continued throughout from the sixth day onwards.

ACKNOWLEDGMENTS

The author wishes to express his deep sense of gratitude to Rao Bahadur B. Viswanath, F.I.C., F.C.S., Director, Imperial Agricultural Research Institute, New Delhi, and formerly Agricultural Chemist to the Government of Madras, and also to Mr. P. D. Karunakar, M.Sc. (U. S. A.), Agricultural Bacteriologist, Agricultural Research Institute, Coimbatore, for their valuable help and advice tendered during the course of this investigation.

REFERENCES

Beijerinck, M. W. (1888). *Bot. Ztg.* **46,** 726-735, 741-750, 757-771, 781-790, 797-804

Bewley, W. F. and Hutchinson, H. B. (1920). *J. Agric. Sci.* (*England*) **10**, 144-162

Gangulee, N. (1926). *Ann. Appl. Biol.* **13,** 256-259 ; 360-373

Gibson, T. (1928). *J. Agric. Sci.* (*England*) **18,** 76-89

Löhnis, F. (1905). *Zbl. Bakt.* (*Abt. 2*) **14,** 582-604, 713-723

——— (1921). *Mem. Nat. Acad. Sci.* (*Washington*), 1-335

Löhnis, F. and Hansen, R. (1921). *J. Agric. Res.* (*U. S. A.*) **20,** 543-556

Löhnis, F. and Smith, N. R. (1916). *J. Agric. Res.* (*U. S. A.*) **6,** 675-702

Thornton, H. G. and Gangulee, N. (1926). *Proc. Roy. Soc.* (*Ser. B*) **99,** 427-451

STUDIES ON GROUNDNUT NODULE ORGANISM

III. PHYSIOLOGY OF THE ORGANISM: FERMENTATION CHARACTERISTICS*

BY

T. RAJAGOPALAN, B.A., M.Sc.

Assistant to the Government Agricultural Chemist, Agricultural Research Institute, Coimbatore

(Received for publication on 19th July 1937)

(With three text-figures)

THE metabolism of legume bacteria in general has been approached mainly from the standpoint of nitrogen fixation in symbiotic relationship with the host plants with which they are associated. In view of the fact that they play an important role in improving soil fertility by fixing atmospheric nitrogen and also that the energy required for such a fixation is supplied through the oxidation of carbohydrates and other similar organic compounds in nature, it is desirable in the first instance to have a better knowledge regarding the carbon metabolism of these organisms. This aspect of study is rather important and does not appear to have been studied in detail so far by the previous workers in the field.

It has long been known that the root nodule bacteria of the Leguminosæ are capable of fermenting various carbohydrates, resulting in most cases in the production of acids and consequent changes in reaction of the medium in which they are grown. The fermentation characteristics of nodule bacteria in media containing glucose, mannite and other carbohydrates have been studied by Joshi [1920], Müller and Stapp [1925], Baldwin and Fred [1927] and more recently by Foote, Peterson and Fred [1929] and others. The results of these investigations indicate that the carbohydrate utilisation by the bacteria depends on the reaction of the medium, the nature of the carbohydrate, the presence of phosphate, calcium carbonate and other mineral salts present in the medium.

No systematic attempt seems to have been made previously to study the biochemistry of nodule bacteria in relation to the carbon metabolism even in any of the simple carbohydrate media. The object of the investigation reported in this part was therefore to throw more light on this aspect with particular reference to the fermentation characteristics of a selected strain under varied conditions in media containing glucose and other types of ordinary carbohydrates.

---

* Part of a thesis accepted by the University of Madras for the Degree of Master of Science.

Experimental

FERMENTATION CHARACTERISTICS

All the work reported in this paper was carried out with isolate 1. A modification of Ashby's basic medium containing yeast-water and one per cent carbohydrate was used except in cases where the nature of an experiment required special alteration. The carbonate in the medium was reduced to 0·01 per cent and the phosphate increased to 0·05 per cent. The reaction of the medium was adjusted to *p*H 7·0, except in the instance where the effect of reaction on the fermentation characteristics of the organism was studied. The media containing the carbohydrates were sterilised in a steam steriliser to prevent destruction of sugars for three consecutive days, half an hour each day. Inoculations were often effected in 150-c.c. lots of culture solutions in 300-c.c. Erlenmeyer flasks. Determinations of sugars were made and changes in *p*H recorded periodically in samples of cultures drawn aseptically from the flasks. Corrections were also made in the sugars estimated for losses due to evaporation of water from the cultures whenever necessary.

Sugar estimation

This was made by adopting Shaffer and Hartman's [1920-21] macro and micro methods as modified by Stiles, Peterson and Fred [1926] depending on the quantity of sugar in the various media. The micro-method was generally resorted to for cultures containing one per cent and less of sugars and the macro-method in cases where the sugars exceeded the one per cent limit.

p*H determinations*

These were made in 5 c.c. of cultures drawn from time to time, colorimetrically, using Hellige's colour discs.

Experiment 1 : Rate of fermentation of various carbohydrates and the consequent changes in reaction of the media containing them.—The carbohydrates (all pure Merck specimens) used for the study were glucose, galactose, mannose, fructose, xylose, sucrose, maltose, lactose, raffinose and dextrin. One hundred and fifty c.c. lots of Ashby's yeast-water medium (*p*H 7·0) containing one per cent of the various carbohydrates in 300-c.c. conical flasks of uniform size were inoculated after sterilisation, using one c.c. of fresh culture for each flask. The culture solutions were analysed just after inoculation and also at intervals for *p*H and sugar contents. A control flask with no sugar was also included for the study. From the results recorded in Table I, it may be inferred that all the carbohydrates were attacked by the organism but varied in the amounts utilised. The final hydrogen-ion concentration reached at the end of one month in all the media were more or less the same, but for the slight fluctuations noticed here and there during the intermediate stages of fermentation. The figures in the table also reveal a marked fall in the *p*H values of all media between the third and tenth day and subsequently the course of reaction becoming more or less steady and constant, in spite of the progressive increase in the sugars utilised. The hexose sugars, except galactose, were utilised to a greater extent than the other carbohydrates.

TABLE I

Rate of fermentation of various carbohydrates and the consequent changes in reaction

Age of culture	Initial		3 days		7 days		10 days		16 days		22 days		30 days		Sugar utilised at the end of 30 days (per cent)
Carbohydrates	Glucose equivalent (mg.)	*p*H	Glucose equivalent (mg.)	*p*H	Glucose equivalent (mg.)	*p*H	Glucose equivalent (mg.)	*p*H	Glucose equivalent (mg.)	*p*H	Glucose equivalent (mg.)	*p*H	Glucose equivalent (mg.)	*p*H	
1. None	..	7·0	...	7·3	...	7·5	...	7·6	...	7·8	...	7·8	..	7·8	..
2. Glucose . . .	940	7·0	96	6·5	178	6·0	232	5·6	395	5·3	427	5·1	437	5·0	46·49
3. Galactose . . .	931	7·0	84	6·0	98	5·5	107	5·4	196	5·3	209	5·1	225	5·1	24·17
4. Mannose . . .	936	7·0	140	6·1	252	5·6	272	5·3	297	5·2	324	5·2	348	5·1	32·38
5. Levulose . . .	940	7·0	78	6·3	147	6·0	166	5·5	224	5·3	356	5·1	365	5·1	38·84
6. Xylose . . .	934	7·0	30	6·0	45	5·7	65	5·5	77	5·2	139	5·2	159	5·1	17·02
7. Sucrose . . .	948	7·0	73	6·3	113	6·0	175	5·6	188	5·4	207	5·1	239	5·1	25·22
8. Maltose . . .	935	7·0	68	6·0	107	5·6	142	5·5	200	5·4	209	5·2	213	5·2	22·78
9. Lactose . . .	930	7·0	26	6·3	56	6·3	75	6·3	87	5·5	91	5·1	107	5·1	11·50
10. Raffinose . . .	946	7·0	94	6·3	175	5·6	195	5·5	201	5·3	220	5·1	227	5·1	24·00
11. Dextrin . . .	942	7·0	78	6·3	134	6·0	172	5·7	191	5·5	204	5·1	210	5·1	22·29

Again, leaving lactose and xylose which were least attacked by the organism, all the remaining sugars including dextrin and galactose with the exception of other hexose sugars, were utilised almost to the same extent. In the control without sugar there was a progressive increase in *p*H and the difference noticed over the initial reaction was 0·8. This increase in *p*H might be attributed to the attack by the organism of acid radicals especially the phosphate and the consequent release of the bases which would tend to raise the *p*H. The comparative utilisation of the different sugars is also graphically represented in Fig. 1.

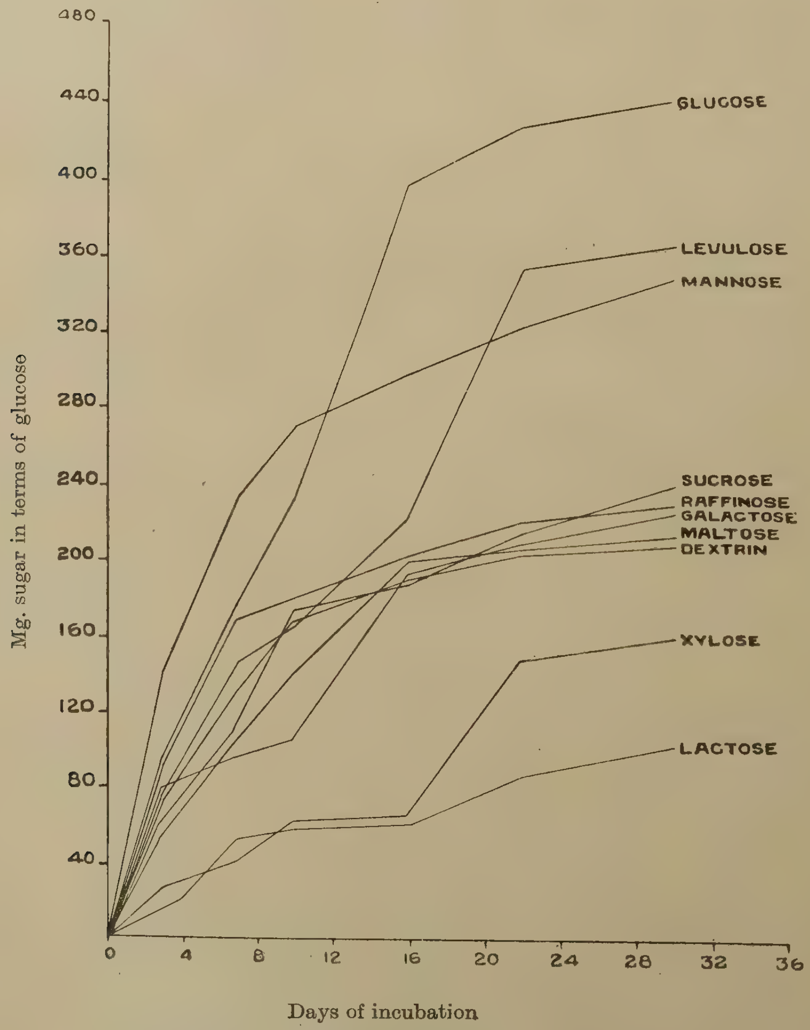


FIG. 1. Showing rate of carbohydrate utilisation

Having established that among the various sugars tried, glucose was used to the maximum extent by the organism, a series of experiments was designed to study the rates of fermentation of this sugar in Ashby's yeast-water medium at *p*H 7·0 under varied conditions.

Experiments 2 and 3 : Influence of buffer salt (K_2HPO_4) *on glucose utilisation and the corresponding changes in reaction of the cultures.*—In connection with this study two sets of experiments were conducted, the first one in media having a fixed quantity of glucose (about one per cent) and different amounts of potassium hydrogen phosphate and the second in cultures with varying concentrations of both. One hundred and fifty c.c. portions of Ashby's mannite medium (*p*H 7·0) with glucose and phosphate in different proportions were distributed in 300-c.c. conical flasks and inoculated as usual after sterilisation using one c.c. of fresh culture for each flask. One flask, without phosphate, and adjusted to *p*H 7·0, was left as control in each set. The results of the periodical analysis of the cultures under the first set for *p*H and sugar as well as for the titratable acidity at the end of one month are given in Table II and the corresponding figures for the second set analysed at the end of a fortnight are recorded in Table III. These experiments go to show that the glucose utilised increased both with the increasing concentrations of the sugar within the limits tried and also with potassium hydrogen phosphate. From the last columns of the two tables it may be seen that the amounts of titratable acidity also increased with the increase in concentration of phosphate and incidentally with the amounts of glucose utilized. It is also interesting to note that the final *p*H values of cultures having higher concentrations of phosphate (above 0·1 per cent) were not in accordance with the increase in titratable acidity but were more or less the same showing practically no deviation from the initial reactions.

TABLE II

Influence of buffer salt, K_2HPO_4, on glucose utilisation and reaction at intervals

Age of culture	Initial		3 days		7 days		15 days		21 days		30 days		Percentage sugar utilised at the end of 30 days	Titratable acidity $N/10$ KOH per 100 c.c. culture (c.c.)
Phosphate concentration in 100 c.c. culture	Glucose present in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H		
No P	946	7·3	58	7·2	169	7·2	188	7·1	249	7·0	254	7·0	26·85	2·8
0·05 per cent K_2HPO_4 . .	946	7·0	97	6·2	178	5·8	232	5·6	374	5·3	427	5·2	45·14	4·7
0·1 per cent K_2HPO_4 . .	946	7·0	155	6·9	228	6·8	255	6·7	388	6·4	460	6·3	48·61	5·3
0·2 per cent K_2HPO_4 . .	946	7·2	164	7·1	262	7·0	302	7·0	422	6·8	495	6·7	52·34	6·4
0·5 per cent K_2HPO_4 . .	946	7·3	177	7·2	269	7·2	334	7·1	481	7·0	508	7·0	53·73	8·6
1·0 per cent K_2HPO_4 . .	946	7·4	189	7·3	321	7·3	388	7·2	504	7·1	527	7·1	55·59	12·2

TABLE III

Influence of buffer salt, K_2HPO_4, on glucose utilisation and reaction in cultures with varying concentrations of both

Glucose and phosphate concentrations in 100 c.c. culture (per cent)	Initial *p*H	Final *p*H at the end of 15 days	Sugar utilised at the end of 15 days in 100 c.c. culture (mg.)	Titratable acidity, *N*/10 KOH per 100 c.c. culture at the end of 15 days
				c.c.
0·5 per cent glucose with no phosphate.	7·2	7·1	163	0·8
0·5 per cent glucose with 0·1 per cent K_2HPO_4.	7·3	7·1	249	1·0
0·5 per cent glucose with 0·2 per cent K_2HPO_4.	7·4	7·2	272	1·2
0·5 per cent glucose with 0·5 per cent K_2HPO_4.	7·4	7·3	298	4·0
1·0 per cent glucose with no phosphate.	7·3	7·2	252	1·0
1·0 per cent glucose with 0·1 per cent phosphate.	7·3	7·1	320	1·2
1·0 per cent glucose with 0·2 per cent phosphate.	7·3	7·2	346	2·2
1·0 per cent glucose with 0·5 per cent phosphate.	7·4	7·3	387	5·6
2·0 per cent glucose with no phosphate.	7·3	7·0	415	1·2
2·0 per cent glucose with 0·1 per cent phosphate.	7·3	7·2	545	1·4
2·0 per cent glucose with 0·2 per cent phosphate.	7·4	7·3	622	2·4
2·0 per cent glucose with 0·5 per cent phosphate.	7·5	7·4	695	10·2

Experiment 4 : The rate of utilisation of glucose in Ashby's yeast-water medium (p*H 7·0*) *containing varying concentrations of sugar and the changes in hydrogen-ion concentration.*—It has been observed incidentally in connection with the previous experiment on the influence of buffer salt on glucose utilisation, that the fermentation of the energy material varied according to its concentration in a medium. The following experiment was planned and conducted to get a more detailed information regarding the extent and nature of the carbohydrate utilisation with reference to varying amounts of glucose in Ashby's yeast-water medium (*p*H 7·0).

One hundred and fifty c.c. portions of Ashby's yeast-water medium (*p*H 7·0) in six 300-c.c. Erlenmeyer flasks containing varying concentrations of glucose ranging from 0·5 to 3 per cent were sterilised and inoculated as usual. The cultures were incubated at 28° C., and analysed for *p*H and residual sugars at intervals. The results are shown in Table IV.

TABLE IV

Influence of glucose concentration on reaction and its utilisation at intervals

Age of culture		3 days		7 days		15 days		21 days		30 days	
Glucose concentration at start in 100 c.c. medium (per cent)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H
0·5 per cent . .	7·2	48	6·9	104	6·5	247	5·7	381	5·3	500	5·1
1·0 per cent . .	7·2	82	7·0	237	6·6	338	5·9	385	5·4	564	5·1
1·5 per cent . .	7·2	94	6·8	258	6·7	396	5·8	502	5·4	623	5·2
2·0 per cent . .	7·2	126	7·1	354	6·8	461	5·7	525	5·3	703	5·3
2·5 per cent . .	7·2	217	7·0	448	6·7	577	6·0	698	5·5	832	5·3
3·0 per cent . .	7·2	390	7·0	698	6·8	807	6·2	907	5·6	996	5·4

The amounts of glucose utilised by the organism in the different cultures, as may be seen from the table, varied considerably and they all increased with the increase in the initial concentration of the carbohydrate in the media. The differences in the amounts of glucose added and utilised seem to have no effect on the hydrogen-ion concentration of the cultures at the end of thirty days.

Experiment 5 : Influence of varying concentrations of carbonate on the utilisation of glucose and reaction of the medium.—Ashby's yeast-water medium containing one per cent dextrose and adjusted to *p*H 7·0 was distributed in four 300-c.c. conical flasks at the rate of 150 c.c. for each flask. After the addition of varying amounts of calcium carbonate to the flasks they were sterilised as usual and inoculated each with one c.c. of fresh culture of the organism. Determinations of *p*H and residual sugars in the cultures were made at intervals and also at start, immediately after inoculation, in samples drawn aseptically from the flasks. The outstanding feature of the experiment, as may be seen from Table V, was the rapid utilisation of sugars in media containing higher concentrations of calcium carbonate without any appreciable alteration in *p*H. The initial *p*H values were not altered appreciably even at the end of one month in cultures containing 0·5 and one per cent calcium carbonate though the amounts of glucose consumed by the organism in these media were considerably greater than in the rest.

TABLE V

Influence of carbonate ($CaCO_3$) *on glucose utilisation and change in reaction*

Age of culture	Initial		3 days		7 days		15 days		21 days		30 days	
Concentration of $CaCO_3$ in 100 c.c. medium (per cent)	Glucose present in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H
0·1 per cent . . .	942	6·9	105	5·9	173	5·8	232	5·2	374	5·1	434	5·1
0·2 per cent . . .	942	7·1	116	6·9	244	5·5	293	5·4	429	5·3	452	5·3
0·5 per cent . . .	942	7·3	230	7·1	466	7·0	520	7·0	621	7·0	654	7·0
1·0 per cent . . .	942	7·5	298	7·3	492	7·2	586	7·2	656	7·2	686	7·2

Experiment 6 : The influence of varying concentrations of nitrate (KNO_3) *on the reaction and utilisation of glucose in Ashby's medium.*—One hundred and fifty-c.c. portions of Ashby's medium with one per cent glucose at initial *p*H 7·1 to 7·2 and containing various concentrations of potassium nitrate were sterilised and inoculated as usual with one c.c. of a young culture of the organism. Two cultures, one containing no nitrate and the other with 0·02 per cent potassium nitrate and yeast-water (ten per cent), were also included in the study. In all, seven flasks were set up and the rates of fermentation in the various cultures measured periodically by determining residual sugars and changes in reactions in aseptically drawn samples.

TABLE VI

Influence of nitrate (KNO_3) on glucose utilisation and change in reaction

Age of culture	Initial		3 days		7 days		15 days		21 days		30 days		
Concentration of KNO_3 per cent in 100 c.c. culture	Glucose present in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Titratable acidity or alkalinity at 30 days *N*/10 KOH or *N*/10 H_2SO_4
No KNO_3	942	7·1	...	7·2	...	7·1	...	7·2	...	7·2	...	7·2	...
0·02 per cent KNO_3 . .	942	7·2	90	7·0	136	6·8	169	6·4	279	5·7	343	5·1	1·0 c.c. alkali
0·05 per cent KNO_3 . .	942	7·2	98	7·1	147	6·8	175	6·5	348	5·9	360	5·6	1·2 c.c. alkali
0·1 per cent KNO_3 . .	942	7·2	106	7·0	173	6·9	208	6·7	370	6·4	417	6·0	2·6 c.c. alkali
0·2 per cent KNO_3 . .	942	7·2	118	7·5	230	8·0	214	8·5	389	8·6	495	8·5	1·5 c.c. acid
0·5 per cent KNO_3 . .	942	7·2	186	7·6	286	8·4	318	8·8	412	8·9	533	8·9	7·2 c.c. acid
Yeast-water 10 per cent *plus* 0·02 per cent KNO_3	942	7·2	192	6·5	378	6·3	501	5·4	532	5·2	597	5·1	10·3 c.c alkali
Yeast-water medium complete with no KNO_3	942	7·1	173	6·6	312	5·9	494	5·3	512	5·1	538	5·0	7·2 c.c. alkali

A reference to the figures in Table VI shows that glucose utilised increases with the concentration of potassium nitrate. In the medium without potassium nitrate and yeast-water there was practically no growth throughout the entire period of incubation and this observation was confirmed by the absence of any loss of sugar in the culture and also by the constancy of its *p*H value even at the time of final analysis. The acid reaction was evident in the cultures with 0·02, 0·05 and 0·1 per cent concentrations of potassium nitrate and the amounts of glucose utilised in these cultures were comparatively lower than in the rest excluding, of course, the culture without nitrate or yeast-water. The maximum utilisation of sugar was observed in the medium with potassium nitrate (0·02 per cent and yeast-water). Another interesting point to be noted in the experiment was the increased alkalinity of the cultures having 0·2 and 0·5 per cent potassium nitrate.

Experiment 7 : The rate of utilisation of glucose in the presence of varying concentrations of peptone and the consequent changes in reaction in one per cent dextrose Ashby's medium.—It has been proved by Kligler [1916], Foster [1921] and others working with some of the pathogenic organisms, that the concentrations of peptone in a medium influence the utilisation of glucose, resulting invariably in a lower final *p*H with a low peptone concentration of the medium. In a few cases the presence of peptone, within certain limits of concentration, acts also as a buffer allowing all the sugar present in a medium to be used up by the organism with a subsequent rise in *p*H, due to the setting up of an alkaline phase brought about by the splitting up of the peptone molecules. The following experiment was started to have an idea regarding the behaviour of the groundnut nodule organism towards peptone present in varying concentrations in one per cent dextrose Ashby's medium at *p*H 7·0.

Six 300-c.c. Erlenmeyer flasks containing 150 c.c. of Ashby's medium with one per cent glucose and varying concentrations of peptone ranging from 0·02 to 0·5 per cent were sterilised and inoculated as in the previous experiments. An additional flask with one per cent peptone and ten per cent yeast-water was also included in the study to compare the rate of fermentation of glucose in the presence and absence of yeast-water with a given concentration of glucose and peptone. Periodical analyses of the samples drawn aseptically from the various flasks were made for sugar and pH values and the results obtained are recorded in Table VII.

TABLE VII

Influence of peptone on glucose utilisation and reaction

Age of culture	Initial		3 days		7 days		15 days		21 days		30 days	
Concentration of peptone per cent in 100 c.c. culture	Glucose present in 100 c.c. culture (mg.)	pH	Glucose utilised in 100 c.c. culture (mg.)	pH	Glucose utilised in 100 c.c. culture (mg.)	pH	Glucose utilised in 100 c.c. culture (mg.)	pH	Glucose utilised in 100 c.c. culture (mg.)	pH	Glucose utilised in 100 c.c. culture (mg.)	pH
0·02 per cent . .	943	7·5	47	7·5	184	7·1	283	6·5	521	5·2	775	5·1
0·05 per cent . .	943	7·5	55	7·5	211	7·0	382	6·9	627	6·2	807	5·1
0·10 per cent . .	943	7·5	76	7·4	361	6·9	455	6·5	667	7·1	943	7·5
0·20 per cent . .	943	7·5	92	7·1	470	6·9	636	6·3	837	7·5	943	7·7
0·50 per cent . .	943	7·5	85	7·5	310	7·6	525	7·6	597	7·8	672	7·8
1·00 per cent *plus* 10 per cent yeast-water	943	7·5	179	6·5	552	6·1	656	5·6	886	6·9	943	7·5

An examination of the figures in the table shows that the rate of utilisation of glucose is influenced to a great extent by the added peptone. In cultures containing 0·02 per cent to 0·2 per cent peptone the sugar consumed gradually increased and was almost completely destroyed before the 30th day. In the case of yeast-water medium with one per cent peptone the rate of destruction of glucose was the greatest and the added sugar was used up much earlier than in the other media. In cultures 3, 4, and 6 where the destruction of sugar was complete before the 30th day, the pH values decreased gradually up to the 15th day and thereafter increased and became definitely alkaline.

Experiment 8 : The influence of initial pH *on the rate of utilisation of glucose in Ashby's yeast-water medium and the consequent change in reaction.*—The influence of hydrogen-ion concentration in fermentation experiments has been demonstrated by a number of investigators. The effect of the variation in the true acidity or alkalinity of a culture is generally revealed in altered rates of growth of an organism and fermentation of the carbohydrate added. The final hydrogen-ion concentration reached in a medium will also be affected in some cases and may vary with the initial reaction of the culture. To get an insight into these factors, especially as to how far the fermentation of glucose is affected by the groundnut nodule organism in Ashby's yeast-water medium adjusted to varying reactions, the following experiment was designed.

Four 300-c.c. conical flasks of uniform size, containing 150-c.c. portions of Ashby's yeast-water medium adjusted to varying reactions, ranging from pH 6·0 to 9·0 at unit intervals, were sterilised and inoculated each with one c.c. of a week old culture as in the previous experiments. Flasks were all incubated as usual at 28° C. and samples drawn from them with aseptic precautions at intervals for the estimation of sugar and change in reaction. From the results entered in Table VIII, it may be seen that there is a maximum utilisation of sugar in the flask with the initial *p*H of 7·0 and least in the culture at *p*H 6·0. The amounts of sugar destroyed in the other flasks on the alkaline side were more or less the same and they were considerably less than the amount utilised in the culture at *p*H 7·0.

TABLE VIII

Influence of initial p*H on glucose utilisation and reaction*

Age of culture	Initial		3 days		7 days		15 days		22 days		30 days	
Initial reaction of culture	Glucose present in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H
6·0	948	6·0	29	5·8	44	5·6	104	5·5	188	5·3	232	5·2
7·0	948	7·0	105	5·6	182	6·1	384	5·6	417	5·3	442	5·3
8·0	948	8·0	91	7·1	161	6·5	307	5·9	321	5·4	335	5·3
9·0	948	9·0	62	7·5	133	6·7	265	6·2	296	5·5	301	5·3

Experiment 9 : The rate of utilisation of glucose and the change in reaction in Ashby's yeast-water medium with one per cent glucose in the presence and absence of $CaCO_3$ and K_2HPO_4.—In the previous experiments on the rate of glucose utilisation in the presence of varying concentrations of calcium carbonate and potassium hydrogen phosphate it was noticed that the sugar consumed varied with the relative amounts of these substances in a medium. To see therefore whether there is any sugar utilisation at all in cultures free from either phosphate or carbonate and also to have an idea of the relative extent of fermentation in them, if any, when compared with what would take place in a complete Ashby's medium, the following experiment was carried out.

One hundred and fifty-c.c. lots of Ashby's glucose medium (*p*H 6·8) with no carbonate or phosphate were distributed in two conical flasks of uniform size. To one of these flasks was added 0·1 per cent calcium carbonate and to the other 0·05 per cent potassium hydrogen phosphate. A third flask containing a similar volume of complete Ashby's yeast-water medium with the same amounts of glucose, phosphate, and carbonate as in the other two media was also set up for the sake of comparison. The flasks after sterilisation were inoculated as usual and the cultures analysed periodically for residual sugars and changes in reaction. The results obtained are tabulated in Table IX and are also graphically represented in Fig. 2. It is evident from the table that the organism is capable of utilising glucose to an appreciable extent even in the absence of phosphate or carbonate, but there were variations in the extent of fermentation of the carbohydrate in the media containing either of these two substances.

TABLE IX

Glucose utilisation and change in reaction in presence and absence of $CaCO_3$ and K_2HPO_4 in Ashby's yeast-water medium

Age of culture	Initial		3 days		7 days		15 days		22 days		30 days	
Nature of medium	Glucose present in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H	Glucose utilised in 100 c.c. culture (mg.)	*p*H
Ashby's yeast-water medium complete	946	7·0	97	6·3	182	6·2	248	5·7	403	5·3	452	5·2
Ashby's yeast-water medium without $CaCO_3$	946	7·0	73	5·4	94	5·3	202	5·3	304	5·2	319	5·2
Ashby's yeast-water medium without K_2HPO_4	946	7·0	58	7·3	87	7·3	189	7·2	248	7·2	254	7·2

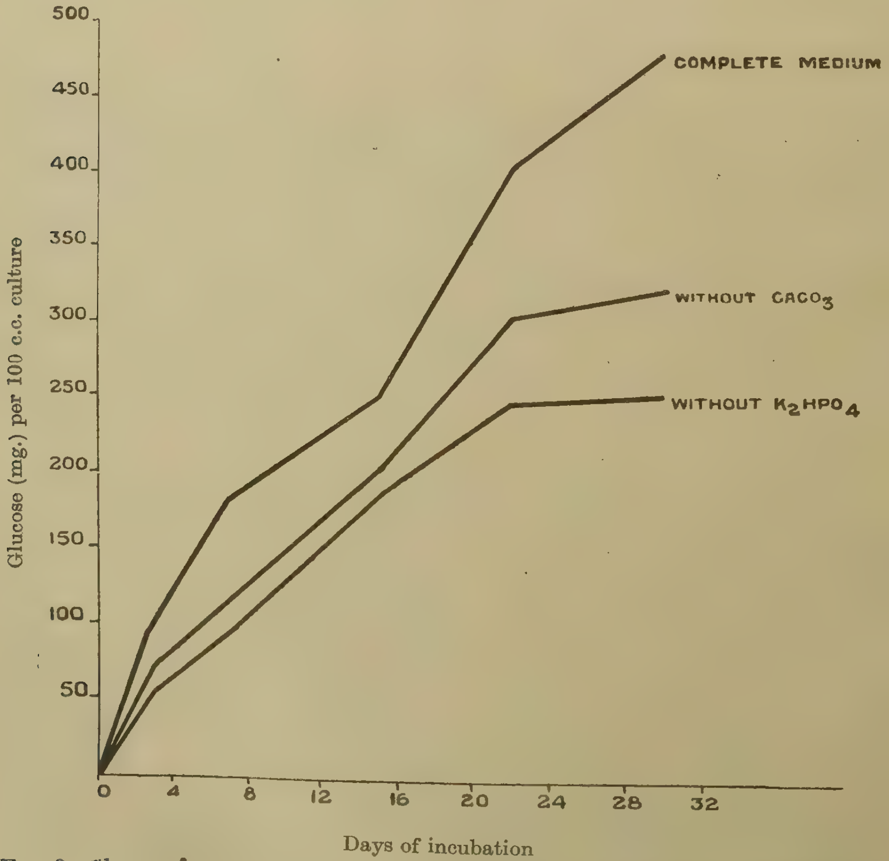


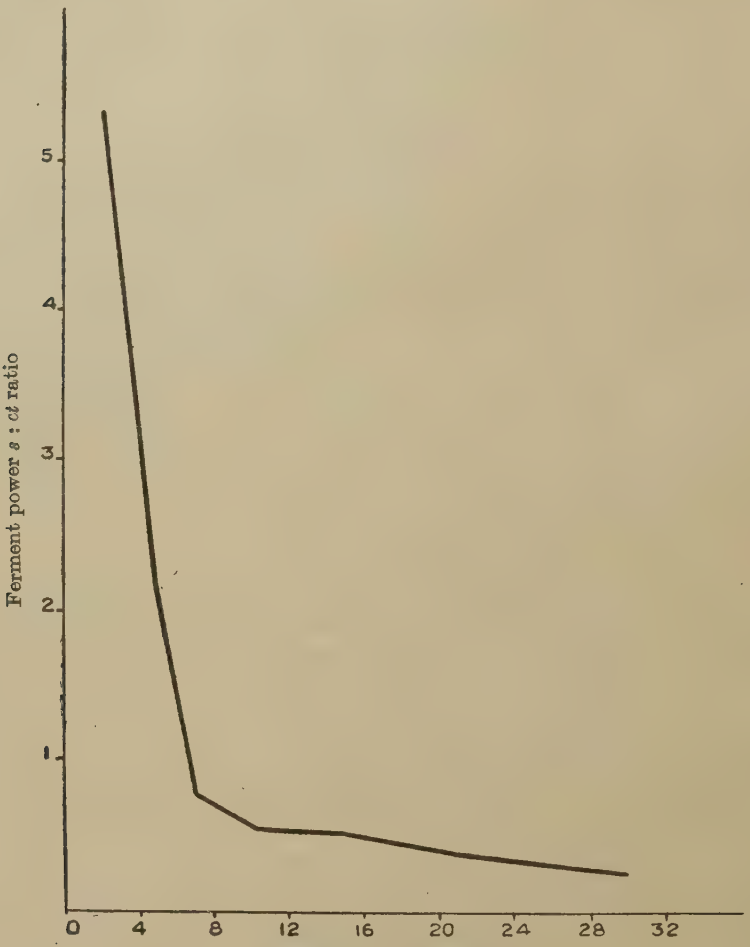
FIG. 2. Glucose fermentation in presence and absence of $CaCO_3$ and K_2 HPO_4 in Ashby's yeast-water medium

Experiment 10 : Rate of sugar fermentation with reference to cell synthesis at intervals or s : ct *ratios.*—It might be obvious from the series of fermentation experiments reported so far that the utilisation of glucose is rapid during the earlier stages of fermentation, *i.e.*, within ten days. It might be presumed that the major portion of the carbohydrates thus destroyed in the initial stages might be found in the cells or the by-products accumulated in the culture medium or liberated as carbon dioxide due to respiration processes. It has also been brought out in the earlier part of this paper (Part I) in connection with the studies on strain variations of the organism that the utilisation of carbohydrate considered in relation with the mass of active cells at work presented some interesting features and indicated the possibility of measuring the relative activity of the different strains as nitrogen fixers. Before attempting to investigate into the nature of the decomposition of the carbohydrate in relation to the by-products formed in a medium it was considered essential to have a more detailed information regarding the ferment power of the organism at different periods for a proper understanding of its physiology. With this end in view, the experiment detailed below was started and the 'ferment power' of the organism determined at close intervals in Ashby's yeast-water medium (*p*H 7·0).

One hundred c.c. portions of Ashby's yeast-water medium (*p*H 7·0) containing one per cent glucose were distributed into a series of 300-c.c. conical flasks of uniform size. The flasks after sterilisation and inoculation were incubated at 28° C. for varying periods of time. A set of two flasks was left uninoculated to serve as control. The dry weight of cells in the cultures and the residual sugars in them were determined as before. The results of analysis conducted in duplicate at different periods are set forth in Table X.

TABLE X

Age of culture Days (*t*)	Sugar consumed (mg.) in 100 c.c. culture (*s*) (Average of two determinations)	Cell synthesised (mg.) in 100 c.c. culture (*c*) (Average of two estimations)	Ferment power *s* : *ct*
2	75	7·0	5·35
5	140	12·8	2·19
7	168	28·0	0·75
10	254	45·2	0·56
15	376	48·0	0·52
21	415	49·6	0·40
30	430	52·8	0·27



[Days of incubation

FIG. 3. Ferment power of the organism at intervals

From a review of the data recorded and also from Fig. 3 it may be seen that the ferment power ($s : ct$ ratio) of the organism while being great and showing wide variations in the earlier stages of fermentation, less than ten days, tends to become less and less as the period of incubation advances. In other words, the efficiency of the organism as measured by the economic utilisation of sugar by a unit weight of cellular substance in a unit of time, becomes greater with increase in age of the culture. For instance, during the first two days of growth 5·35 mgs. of sugar are utilised by a unit of cellular substance in a unit of time, but after an incubation period of thirty days 0·27 mg. of sugar alone is utilised by every unit of cellular matter in a similar unit of time. Thus, the introduction of time element in the fermentation studies, as done by Pasteur [1876], Duclaux [1898-1901] and others, seems to have an important bearing on the physiology of the organism under study. The values for the ‘ ferment power ’ as it is conceived in the present investigation would appear therefore to serve as a better index not only of the efficiency of the organism as a ferment but also of its growth capacity than the mere $s:c$ ratio which shows only the absolute amount of sugar consumed by a unit of cellular matter irrespective of time during which it is formed. Two facts are thus brought out prominently from this experiment, namely (1) the ‘ ferment power ’ of the organism is not constant throughout the life-cycle of the organism and (2) the organism during its earlier stages of fermentation, below ten days, evidently converts the sugar at a very rapid rate into other by-products without a proportionate increase in the rate of synthesis of cellular substance.

Discussion of the results

From the foregoing experiments on the fermentation characteristics of the groundnut nodule organism it appears that the bacterium can carry the fermentation of the various carbohydrates to a definite level of hydrogen-ion concentration under a given set of conditions, probably with the ultimate cessation of its activity. This final hydrogen-ion concentration brought about in the media might be regarded as a physiological constant for the organism under study. The extent of change in pH though serving as an index of the metabolic activities of the organism, does not, however, give a true idea of the fermentative value of the carbon compounds. Even when there is only a small amount of carbohydrate utilisation by an organism, the change in reaction may be well defined. This is also clear from the present investigation where, in spite of the varying amounts of carbohydrates utilised by the organism, the final pH values reached were more or less identical in all cases. The change in pH depends on many factors, chiefly the amounts of carbohydrates utilised and on the nature and quantity of acids formed in a medium. An organism may bring about complete destruction of sugars in a medium with the production of alcohols, acetone, etc., besides weak carbonic acid, without appreciably changing its reaction. The utilisation of small quantities of carbohydrate, on the other hand, with the production of stronger acids such as acetic, lactic and succinic acids may result in a marked change of pH values. The usual practice of measuring the fermentation characteristics of an organism based entirely on pH changes is not reliable and must be considered in relation with the actual quantities of sugar consumed and on the nature and amounts of acids produced in a medium.

The experiments conducted with glucose reveal that the fermentation of this sugar is affected by a number of factors such as (i) the presence of buffer salts, (ii) calcium carbonate, (iii) peptone, (iv) initial reaction, (v) concentration of sugar in a medium. The influence of buffer salts according to Kligler [1916], Foster [1921] and others is to keep the hydrogen-ion concentration below the lethal point and prolong the activity of the organism over a longer period. As a result of this regulating power the amounts of sugar utilised may vary within limits according to the nature and relative amounts of buffer salts present in a medium. This phenomenon is best illustrated in the experiments with cultures well buffered with dipotassium hydrogen phosphate. For instance, in the medium with one per cent dipotassium hydrogen phosphate, though the acid produced was the greatest, the change in the final *p*H from the initial reaction was negligible. This observation while emphasising the importance of buffer salt like dipotassium hydrogen phosphate for maintaining the reaction of a medium at the normal level conducive to a good growth of the organism, reveals also that the final *p*H level reached, rather than the increased acidity, is responsible for limiting the fermentative activity of the bacterium. The fermentation of glucose was more vigorous and considerably greater in a culture having both nitrate (0·02 per cent) and yeast-water than in any of the pure nitrate media. This is evidently due more to the presence of growth-promoting substances in the yeast-water than to the small quantity of the nitrate added. The alkaline reaction of the cultures rich in nitrates (0·2 per cent and above) is presumably set up by the attack of the nitrate radical by the organism and the consequent release of the strong potash base. The nature and path of the nitrate attack is not yet clear. It is postulated that the organism might attack the nitrate either for the nitrogen necessary for the synthesis of the complex protein matter constituting a component part of the cells, or for the oxygen present therein to meet its energy requirements. In the latter process there is likely to be loss of nitrogen and the organism may be considered in that case as a denitrifier. This point deserves careful consideration in view of the fact that the nodule organism is invariably found in nature associated with nitrates and other organic nitrogenous compounds in process of nitrification. In peptone cultures also, there was a progressive and almost complete destruction of the added sugar within a month, so long as the concentration of peptone in the media did not exceed 0·2 per cent. Beyond this limit the sugar utilised becomes less and less with the increasing concentrations of peptone in the cultures and practically no changes were noticed in the reaction of the media. The setting up of the alkaline phase in cultures with 0·2 per cent and less of peptone after the sugars were almost utilised, go to show the ‘ protein sparing ’ action of the organism, in the sense in which this term is understood in the present investigation, namely, the economy of peptone attack in presence of readily available carbohydrates. The presence of yeast-water along with a given amount of peptone also appears to stimulate the activity of the organism to a great extent as evinced from the maximum utilisation of sugar in this culture in a much shorter period than in a similar medium without yeast-water. The amount of sugar consumed by the organism in Ashby's yeast-water medium containing either phosphate or carbonate alone was less than fifty per cent of the quantity utilised in a normal culture having both. Between the phosphate and carbonate cultures, the glucose utilised was greater in the former. The final reactions in these two media differed considerably. The little or no change in *p*H observed in the carbonate culture is probably brought about by the neutralisation of the acids produced in the medium by the carbonate while the lack of such a neutralising agency might be responsible for the acid reaction of the phosphate culture. It would appear from this experiment that for the fermentation to proceed normally to completion there should be present in the medium sufficient amounts of both carbonate and phosphate. The initial reaction of the cultures also seems to affect the rate and amount of glucose fermented in a medium. The ultimate reactions of the media adjusted to varying initial reactions were all equal in spite of great differences in the amounts of glucose consumed by the organism. It appears therefore that the final *p*H, which may be regarded as a physiological constant for the organism under a given set of conditions reached in a medium, is least affected by the absolute quantity of sugar destroyed in the culture. The production of the same final reaction, therefore, in itself does not give an idea of the intensity of fermentation processes taking place in cultures unless their initial *p*H values and their concentrations with reference to buffer salts, peptone, etc., are also known. In media having different concentrations of calcium carbonate, the glucose utilised increased with the increase in the concentrations of the carbonate. The changes in initial *p*H values of cultures, with sufficient amounts of calcium carbonate (0·5 per cent and above) even at the end of one month, were very little, though the amounts of glucose consumed by the organism in these media were considerable. The primary function of the carbonate consists probably in the neutralisation of acids formed in these cultures and thus maintaining their reaction favourable for a vigorous growth of the organism, followed by a rapid destruction of the added sugar. The importance of calcium carbonate as a regulating factor in the fermentation of a given amount of carbohydrate in a cultural medium is clearly brought out in this experiment. The experiments with cultures having varying amounts of glucose, ranging from 0·5 to 3·0 per cent, reveal the capacity of the organism to consume more sugar from media containing higher concentrations of the same with the least possible deviation in the final levels of hydrogen-ion concentration, which tend to become constant and equal in all the media, irrespective of the amounts of glucose consumed by the organism.

Again, the introduction of time element, according to Pasteur [1876], Duclaux [1898-1901] and Bonazzi [1921], in the fermentation studies of the organism has been found to afford valuable information regarding its physiology. It would appear from the experiments on ferment power of the organism (*s* : *ct* ratios) at intervals that there are two distinct phases in the physiology of the organism namely, (i) the first phase corresponding to a period of high ferment power, and (ii) the second one or ' maintenance ' phase of low ferment power, when vigorous cell synthesis takes place. The first phase may be styled as one of preparation when the sugar is converted into complex compounds of non-reducing nature such as acids, alcohols, etc. The products of decomposition are probably further utilised by the organism resulting in the comparatively low ' ferment power ' observed at the end of one month. This finding is also in accord with the statements of the California workers in connection with their studies on *Azotobacter*, to the effect that not sugar but the products of its decomposition form the true sources of energy

(*California Agric. Expt. Stn. Rept.* : 1919, 62-63). Neuberg and his associates [1911] have also shown that even before a monosaccharide can be utilised by an organism it must undergo decomposition. It is probably due to this phenomenon that the organism grows better in the mannite medium than in a glucose culture. Changes of this type have been found to take place in practically all oxidative phenomena by other workers also with the consequent disintegration of the hydro-carbons themselves into lower members of their homologous series.

SUMMARY

1. The organism has been found to attack all the carbohydrates including dextrin in varied amounts, producing the same final hydrogen-ion concentration in all the cultures at the end of one month. Arranged in order of fermentation, glucose ranks foremost, followed by levulose, mannose, sucrose, raffinose, galactose, maltose, dextrin, xylose, and lactose.

2. The studies indicate that the fermentation of glucose depends to a large extent on the concentration of the sugar, the presence of buffer salt (K_2HPO_4), peptone, nitrate, calcium carbonate, initial reaction of the medium, etc.

3. The ferment power of the organism ($s : ct$ ratio, where s is the sugar consumed, c the cell weight and t the period of incubation) is very high during its earlier stages of growth and subsequently diminishes rapidly with the advance in age of the culture. This indicates the existence of two distinct phases in the physiology of the organism, the first stage corresponding to a period of great sugar utilisation with less of cell synthesis—a period of high ' ferment power ', and the second one or maintenance phase of low ' ferment power ', when vigorous cell synthesis takes place.

4. These experiments emphasise, in short, the need for a proper control of a culture medium with reference to its composition, reaction, etc., for the fermentation of a given amount of carbohydrate to proceed normally to completion, besides revealing some of the factors retarding the fermentative activities of the organism.

ACKNOWLEDGMENTS

The author wishes to express his thanks to Rao Bahadur B. Viswanath, F.I.C., F.C.S., Director, Imperial Agricultural Research Institute, New Delhi, and formerly Agricultural Chemist to the Government of Madras, and also to Mr. P. D. Karunakar, M.Sc. (U. S. A.), Agricultural Bacteriologist, Agricultural Research Institute, Coimbatore, for their valuable help and advice tendered during the course of this investigation.

REFERENCES

Baldwin, I. L. and Fred, E. B. (1927). *Soil Sci.* **24**, 217-230

Bonazzi, A. (1921). *J. Bact.* **6**, 331-369

Duclaux (1898-1901). 'Traite' de Microbiologie'. Paris : Masson

Foote, M. ; Peterson, W. H. and Fred, E. B. (1929). *Soil Sci.* **28**, 249-256

Foster, L. F. (1921). *J. Bact.* **6**, 161-239

Joshi, N. V. (1920). *Mem. Dept. Agric. Ind.* (*Bact. Ser.*) **1**, No. 9

Kligler, I. J. (1916). *J. Bact.* **1**, 663

Muller, A. and Stapp, C. (1925). *Arb. Biol. Abt.* (*Anst-Reichsanst*) *Berl.* **14**, 455-554

Neuberg, C. and Hildesheimer, A. (1911). *Biochem. Z.* **31**, 170

Pasteur, L. (1876). 'Etude sur la Biere'. Paris

Shaffer and Hartman (1920-21). *J. Biol. Chem.* **45**, 365

Stiles, H. R. ; Peterson, W. H. and Fred, E. B. (1926). *J. Bact.* **26**, 427-439

STUDIES ON GROUNDNUT NODULE ORGANISM

IV. PHYSIOLOGY OF THE ORGANISM: INTERMEDIARY METABOLISM*

BY

T. RAJAGOPALAN, B.A., M.Sc.

Assistant to the Government Agricultural Chemist, Agricultural Research Institute, Coimbatore

(Received for publication on 19th July 1937)

(With six text-figures)

I. CARBOHYDRATES

In spite of the enormous literature that has accumulated of late on nodule bacteria, information is scanty even with regard to the intermediary metabolism of these organisms with reference to carbohydrate fermentation in synthetic cultures, especially the nature of the by-products formed due to the assimilation of the sugars by them in the media. In short, as Russell [1932] has remarked " Even the changes in the carbohydrates of the culture medium have not been worked out ". From the previous experiments on the fermentation characteristics of strain 1 (part III) in media containing typical carbohydrates and also from similar investigations carried out by other workers in the field, it is evident that the nodule bacteria are capable of attacking the ordinary fermentable carbohydrates rather slowly. The degree and extent of carbon assimilation by these organisms have also been found to vary with the strains, the nature of the carbohydrate, the composition of the medium, etc. The experiments reported below were conducted to gain some knowledge on the intermediary metabolism of the organism with special reference to the points mentioned above in Ashby's dextrose medium at pH 7·0. Incidentally, the carbon balance of the organism was also worked out in Ashby's medium (pH 7·0) having 0·2 per cent potassium nitrate and free from calcium carbonate and yeast-water.

Experiment 1 : Detection and estimation of by-products

Two litres of Ashby's yeast-water medium at pH 7·0 containing one per cent glucose were sterilised and inoculated with 50 c.c. of a week old culture of the organism (strain 1). The culture was incubated at 28°C. for forty-five days and qualitative tests were conducted with the fermented medium for the presence of common fermentation products, such as alcohol, acetaldehyde, acetone, formic, acetic, butyric, tartaric and succinic acids. The reaction of the medium was acidic at the end of the fermentation period. The results of the tests for the volatile non-acidic and acidic portions as well as for non-volatile acids are given in Tables I, II and III.

---

*Part of a thesis accepted by the University of Madras for the degree of Master of Science.

TABLE I

Volatile non-acidic portions

Substances tested for	Nature of test	Result
1. Ethyl alcohol .	1. Iodoform test . . . . 2. Benzoyl chloride test . . .	Positive
2. Aldehyde . . .	1. Ammoniacal solution of $AgNO_3$. 2. Concentrated HNO_3 and $K_2Cr_2O_7$ (0·5 per cent) . . . . 3. Nessler reagent	Positive
3. Acetone . .	1. Sodium nitroprusside test . . 2. Denige's reagent	Negative
4. Acetyl methyl carbinol . .	Modified Voges-Proskauer test .	Negative

TABLE II

Volatile acidic portions

Substances tested for	Nature of the test	Result
1. Formic acid . .	1. Ammoniacal solution of $AgNO_3$. 2. $K_2Cr_2O_7$ (0.5 per cent) in HNO_3 .	Negative
2. Acetic acid . .	1. H_2SO_4 and ethyl alcohol . . 2. Ferric chloride and dilute ammonia	Positive
3. Butyric acid .	Ether and 2 per cent copper sulphate in equal volumes . . .	Negative
4. Propionic acid .	Ferric chloride in presence of acetic ester	Negative

TABLE III

Non-volatile acids

Substances tested for	Nature of the test	Result
1. Lactic acid	1. Formation of zinc lactate 2. Uffleman's reaction 3. Hopkins' reaction	Positive
2. Succinic acid	Ferric chloride reaction	Negative
3. Tartaric acid	1. Resorcinol and H_2SO_4 2. Silver nitrate test	Positive

It is evident from the qualitative tests recorded in the tables above that the by-products formed in the fermentation of glucose by the organism are ethyl alcohol, acetaldehyde, acetic, lactic and tartaric acids besides carbon dioxide.

Quantitative estimation of by-products

Two litres of one per cent dextrose-yeast-water Ashby's medium with one per cent calcium carbonate at *p*H 7·0 were sterilised in a three-litre flask and inoculated with 50 c.c. of a week old culture of the organism. The initial sugar content in the medium was estimated by the macro method of Shaffer and Hartman [1920-21] in a sample drawn aseptically immediately after inoculation. The culture was allowed to ferment at 28°C. for two months and analysed thereafter for residual sugar and other by-products. The results and the procedure adopted for the determination of the various by-products are given below.

1. Sugar fermented

Initial sugar content of the culture after sterilisation in 2,000 c.c. of the medium	18·36 grms. (sugar)
Residual sugar in the medium at the end of sixty days	8·83 grms.
Sugar fermented	9·53 grms.

2. Total acids

These were estimated by direct titration of 50 c.c. of culture against *N*/20 caustic potash using azolitmin as indicator and expressed as number of c.c. of standard alkali. The total acids found in the entire medium (2,000 c.c.) were equivalent to 178 c.c. *N*/20 caustic potash.

3. *Volatile non-acidic portion*

Ethyl alcohol was estimated by distilling 750 c.c. of the fermented medium rendered slightly alkaline to phenolphthalein with normal potassium hydroxide till 200 c.c. remained in the flask. The distillate was subjected to redistillation till 100 c.c. were collected in a measuring flask. The density of the second distillate was determined with the aid of a pyknometer and found to be 0·9966 at 27°C. After making necessary temperature correction the percentage of alcohol in the distillate was 1·28 by volume and by weight 1·03. The amount of alcohol in the whole medium was 2·747 grms.

4. *Volatile acids*

These were determined by Dyer's [1916] modification of Duclaux's steam distillation and titration process. Two hundred c.c. of the fermented medium were acidified with tartaric acid and steam-distilled till 100 c.c. were collected. The distillate was then made up to 110 c.c. and redistilled till 10 c.c. remained in the flask. Portions of 10 c.c. collected separately were titrated against standard alkali ($N/10$ KOH) using phenolphthalein as indicator. The amount of alkali required to neutralise the various portions, the 'distilling constants', were expressed as percentages of the total required to neutralise the sum of all the fractions. The titration values for each of the 10 c.c. portions collected and the corresponding distilling constants are given in Table IV.

TABLE IV

Titration of volatile acid fractions

Fraction No.	$N/20$ alkali required (KOH) (c.c.)	Total volume of distillate in c.c.	Total volume of alkali required $N/20$ KOH (c.c.)	Distilling constant	Duclaux's constant for acetic acid
1 . . .	1·7	10	1·7	7·3	7·4
2 . . .	1·8	20	3·5	15·1	15·2
3 . . .	1·9	30	5·4	23·3	23·4
4 . . .	2·0	40	7·4	31·9	32·0
5 . . .	2·0	50	9·4	40·5	40·9
6 . . .	2·3	60	11·7	50·4	50·5
7 . . .	2·4	70	14·1	60·7	60·6
8 . . .	2·6	80	16·7	72·0	71·9
9 . . .	2·9	90	19·6	84·5	84·4
10 . . .	3·6	100	23·2	100·0	100·0

By plotting the sequence of numbers thus obtained, the distilling constants, against the respective fractions of the distillate a curve is obtained (Fig. 1) characteristic of acetic acid. The values for the distilling constants obtained in the present experiment agree also very closely with those of

Duclaux recorded in the last column of the table. Assuming all the volatile acids are acetic acid, this was estimated as follows :—

Two hundred c.c. of the fermented medium were acidified with tartaric acid and steam-distilled till the liquid passing over was no longer acidic. The distillate was then neutralised with excess of calcium carbonate to fix the volatile acids and boiled to drive off other volatile products such as alcohol, aldehyde, etc. The neutralised medium was concentrated to about 100 c.c. and the free acids liberated by adding sufficient quantity of tartaric acid solution. The solution was then filtered, made up to 200 c.c. and re-distilled till all the volatile acids have passed over. From the amount of $N/20$ sodium hydroxide required to neutralise the distillate collected, the acetic acid content in the whole medium (2,000 c.c.) was calculated and found to be 0·292 grms.

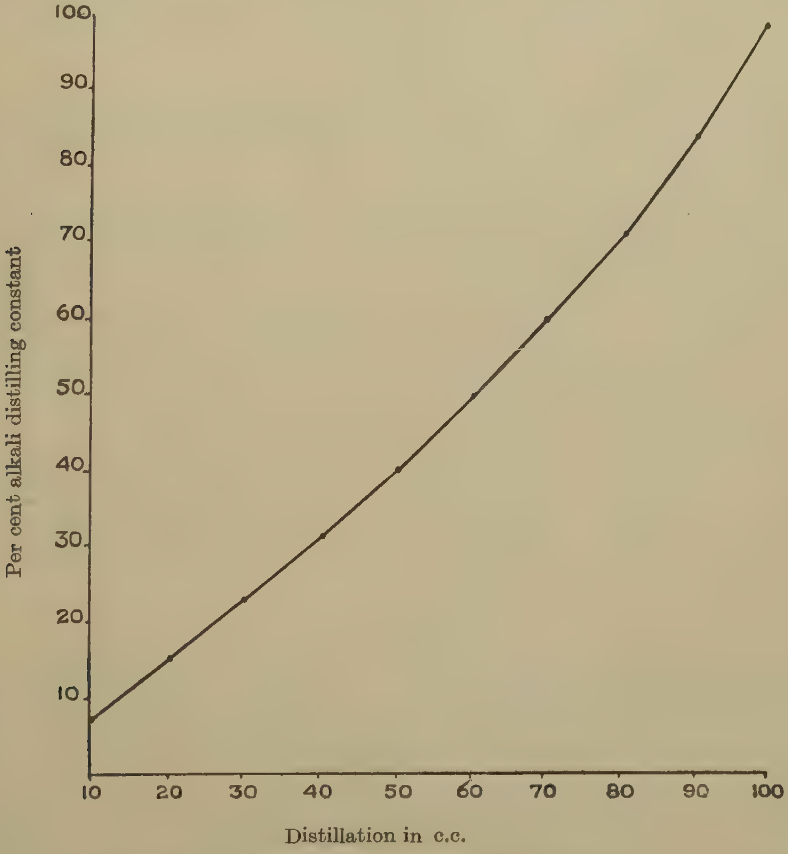


Fig. 1. Duclaux's curve for acetic acid

5. *Non-volatile acids*

(*i*) *Lactic acid.*—Five hundred c.c. of the fermented medium were steam-distilled after being rendered acidic with sulphuric acid. The residue left in the flask after distillation was concentrated to a small volume, about forty to fifty c.c., and extracted several times with ether. The ethereal extracts were mixed together, filtered and the ether evaporated. The syrupy residue left after evaporation was treated with fifty c.c. of water and boiled with excess of pure calcium carbonate. The dissolved calcium was then estimated volumetrically in the filtrate. From the amount of calcium found in solution, the lactic acid present in the entire medium (2,000 c.c.) was calculated. The total amount as estimated by the above method was 1·35 grms.

(*ii*) *Tartaric acid.*—This was determined in 200 c.c. of the fermented medium by adopting the method recommended in A. O. A. C. for the estimation of total and free tartaric acid as well as cream of tartar in wines and similar products. The amount of tartaric acid in 2,000 c.c. of the medium according to this method was 0·307 grm.

(*iii*) *Acetaldehyde.*—This was determined in 200 c.c. of culture by adopting Ripper's [1900] method which is based on the neutralisation of alkali bisulphites with aldehydes. The total aldehyde as estimated by this method in the whole medium was negligible.

Out of 9·53 grms. of sugar fermented, the amounts of the various by-products formed in 2,000 c.c. of the medium, besides carbon dioxide, were alcohol—2·747 grms., acetic acid—0·307 grm. and traces of aldehyde.

In the course of the fermentation experiments carried out before with glucose and other carbohydrates, it was found (part III) that the rate of sugar utilisation was not uniform throughout and the amount consumed was considerably greater in a young culture of the organism than in the later stage. This suggested the possibility of a definite change in the nature of the fermentation after a few days, due probably to the setting up of a secondary fermentation in the intermediate stage of the culture. A similar phenomenon has also been observed in the case of *Azotobacter* by Ranganadhan and Norris [1927]. To get some information on the nature of this fermentation the following experiments were carried out.

Experiment 2

Four three-litre flasks containing two litres each of Ashby's yeast-water medium (*p*H 7·0) with three per cent calcium carbonate were sterilised and inoculated each with fifty c.c. of a young culture of the organism. Sugar determinations were made immediately after inoculation in samples drawn aseptically from all the flasks as before.

Flask No. 1.—This was kept as control and samples (60 c.c.) were drawn at intervals of twenty-four hours for analysis of sugars and volatile acids. Daily analysis was continued till there was a sudden drop in the latter, and subsequently at convenient intervals to gauge the period in which the sugar destruction was almost complete.

Flask No. 2.—This was left undisturbed and taken up for complete analysis when the analysis of the sample from flask No. 1 indicated a fall in the volatile acids.

Flask No. 3.—Was allowed to ferment till flask No. 1 showed that the sugar had been utilised very nearly to completion.

Flask No. 4.—The contents of this flask were allowed to ferment in presence of 2 grms. of sodium bisulphite, the object being to arrest the fermentation at the aldehyde stage, and taken up for complete analysis along with flask No. 3.

The fermentation of the cultures as judged by growth in all the flasks were good except in No. 4, where it was delayed for a longer duration over ten days. From the 15th day onwards, fermentation in this last flask also began to proceed vigorously. The results of the analysis of the various cultures are given in Tables V and VI.

TABLE V

Sugar utilisation and volatile acids formed at intervals in flask No. 1

No. of days of incubation	Residual sugars (grms.)	Sugar fermented (grms.)	Total volatile acids $N/50$ NaOH (c.c.)
At start	18·84	..	..
1	18·62	0·22	12
2	18·30	0·54	28
3	17·37	1·47	36
4	16·64	2·20	45
5	16·36	2·48	56
6	16·10	2·74	72
7	15·64	3·20	96
8	14·86	3·98	124
9	14·24	4·60	146
10	13·16	5·68	154
11	12·42	6·42	116
12	11·70	7·14	132
13	10·94	7·90	142
14	10·48	8·36	156
15	9·54	9·30	168
20	8·90	9·94	182
25	7·38	11·46	194
30	5·19	13·65	212
35	2·33	16·51	226
40	1·35	17·49	240
45	0·60	18·24	256

TABLE VI

By-products of fermentation in flasks 2, 3 and 4

Details of analysis	Culture No. 2 analysed on the 12th day	Culture No. 3 analysed on the 46th day	Culture No. 4 analysed on the 46th day
	Grms.	Grms.	Grms.
Sugar added	18·84	18·84	18·84
Residual sugar at the time of analysis . .	9·64	2·34	2·89
Sugar utilised	9·20	16·50	15·95
Total acids expressed in terms of $N/20$ NaOH required for neutralisation . .	124	96	204
Aldehyde expressed as acetaldehyde . .	0·0296	0·0048	0·056
Volatile acids expressed as acetic acid . .	0·364	0·246	0·480
Lactic acid	3·181	2·623	2·292
Tartaric acid	0·288	0·175	0·149
Alcohol	0·73	2·107	2·367

The methods adopted for the determination of the various by-products have already been described. From the figures recorded in Table VI, it might be inferred that flask No. 2 analysed at the intermediate stage contained more volatile acids than culture 3 which was allowed to ferment completely, though the amount of sugar consumed in the latter was naturally more than No. 2. The amounts of lactic and tartaric acids synthesised in flask No. 2 were also greater than in flask 3 as well as in flask 4. In flask No. 4, to which sodium bi-sulphite was added, the amount of volatile acids produced was the greatest and the aldehyde also, as it might be expected, was considerably greater than in the other two cultures. The increased production of volatile acids in this culture, wherein the fermentation was arrested at the aldehyde stage, throws some light on the probable mechanism of carbohydrate utilisation in a normal culture medium. It appears from this experiment that the first stage in the fermentation of glucose consists primarily of the elaboration of the crude carbohydrate into volatile acids and the subsequent utilisation of these acids and other silmilar by-products as true sources of energy by the organism for its growth and cell synthesis.

Experim ent 3 : Carbon balance

For the determination of the carbon balance, experiments were started in duplicate using Ashby's dextrose medium (pH 7·0) containing known amounts of glucose, 0·2 per cent potassium nitrate but with no calcium carbonate or yeast-water.

The technique adopted for the estimation was more or less the same as that followed by Ranganadhan and Norris [1927] in connection with their studies on *Azotobacter*, with certain modifications. The sketch of the apparatus fitted up for the purpose is shown in Figs. 2, 3 and 4.

One hundred c.c. of dextrose Ashby's medium containing 0·2 per cent KNO_3 and without calcium carbonate or yeast-water were run into the flask A and after sterilisation inoculated with one c.c. of a week old culture of the organism. The flask was then connected to respiration apparatus shown in the diagram (Fig. 2) taking all precautions to maintain sterility. Dry air free from carbon dioxide was aspirated through the culture medium at the laboratory temperature (27°-28°C.) for forty-five days at the rate of fifteen bubbles per minute. The air before entering the flask was purified by passage through the following train :—

1. Bottle E_1 containing 1 : 1 KOH to remove carbon dioxide.
2. Bottle E_2 containing concentrated sulphuric acid to remove moisture.
3. Soda lime tubes F_1 and F_2 to remove any residual carbon dioxide.
4. Calcium chloride tube E to avoid moisture diffusing backwards from the flask.

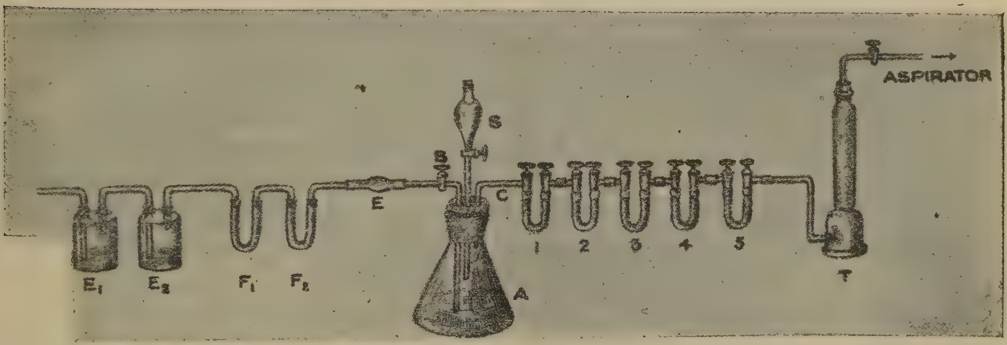


FIG. 2. Respiration apparatus

The air and the carbon dioxide liberated in the flask pass through the following train of absorption tubes :—

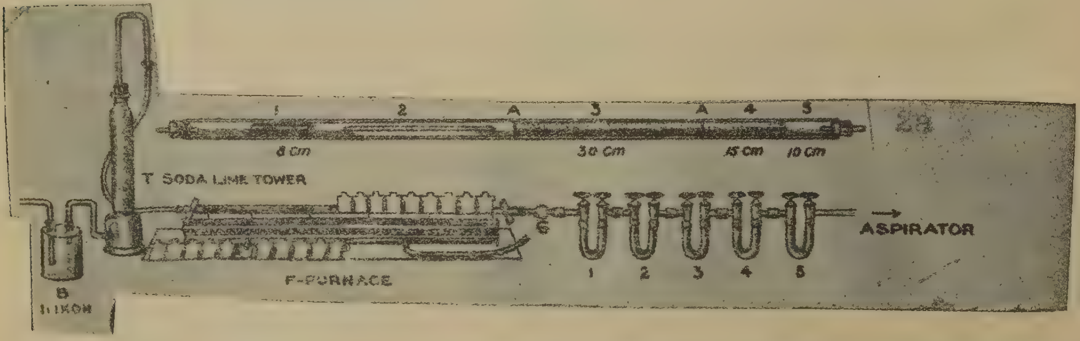
1. U-tube 1 containing pumice (hemp size) soaked in concentrated sulphuric acid for removing water.
2. U-tube 2 containing calcium chloride for removing residual water.
3. Soda lime tubes 3 and 4 having a small amount of calcium chloride at the exit ends, to absorb carbon dioxide evolved.
4. U-tube 5 containing soda lime in one limb and calcium chloride in the other to serve as a guard tube, and
5. Guard tower T containing calcium chloride and soda lime to prevent back diffusion of aqueous vapour and carbon dioxide from the atmosphere.

At the expiry of the incubation period, 3 to 4 c.c. of syrupy phosphoric acid were added to the culture medium in drops by means of the separating funnel, S, to liberate the carbon dioxide that might be present in the medium in chemical combination and the aeration continued for another two hours. The U-tubes 3 and 4 were then weighed, and from the increase in their weights the amount of carbon dioxide evolved in the culture medium due to the fermentation of glucose by the organism was obtained.

The contents of the flask were then filtered over a specially prepared Gooch filter padded with a thick felt of asbestos and Kiesulguhr. The Gooch filter with the asbestos and Kiesulguhr was ignited before filtration to drive off any organic matter that might be present in any of these substances. The bacterial mass left on the filter was washed a number of times with hot water till free from sugar and the washings added to the first filtrate. The filtrate was then made up to a known volume (500 c.c.) and sugar determined in an aliquot thereof. The carbon contents of the filtrate and the bacterial residue dried at 100°C. were determined separately.

Determination of carbon dioxide in the bacterial residue

This was estimated by the modified dry combustion method evolved in this laboratory by Seshadri [1933]. The sketch of the apparatus is given in Fig. 3. It consists of the combustion tube filled as shown separately (upper figure) and the purifying and absorption trains. The air before aspiration was bubbled through 1 : 1 KOH in Woulffe's bottle and subsequently through a big soda lime tower. The absorption train consists of a calcium chloride bulb G and five U-tubes filled and fitted in the same way as in the respiration experiment (Fig. 2).



Upper figure.—1. Oxidised copper coil ; *2.* Silver boat ; *3.* Copper oxide lead chromate mixture ; *4.* Silver wire. A. A. Asbestos plug

FIG. 3. Apparatus to determine carbon dioxide in the bacterial residue.

Carbon estimation in the filtrate

A convenient aliquot, 100/500, was taken for the estimation. The method adopted was that of Gortner [1916] with certain modifications. A sketch of the modified apparatus used is given in Fig. 4 and it consists of (1) Kjeldahl flask, C, (2) the separating funnel, B, (3) condenser, D, (4) Woulffe's bottle, E, containing concentrated sulphuric acid to remove moisture and traces of sulphur oxides, (5) the combustion furnace with the absorption train consisting of calcium chloride bulb G and U-tubes 1, 2, 3, 4 and 5, filled and fitted in the same manner as in Fig. 3, and (6) the aspirator. During the first two hours of aspiration, the contents of the flask were kept just below the boiling point by means of a low flame. The carbon dioxide evolved was determined by the increase in weights of the soda lime tubes 3 and 4 in the absorption train as in the previous experiment. These methods were previously tested with pure organic compounds such as sucrose, uric acid, glucose, etc. The results of the experiment conducted in duplicate are set forth in Table VII.

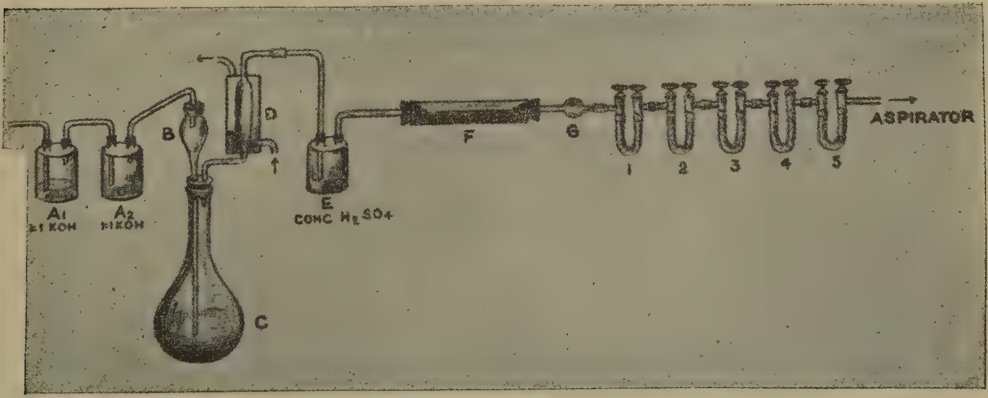


FIG. 4. Apparatus for the estimation of carbon in the filtrate

TABLE VII

Carbon balance results

No.	Details of analysis	Experiment 4		Experiment 5	
		Actual grms.	Recovery CO_2 (per cent)	Actual grms.	Recovery CO_2 (per cent)
1	Sugar present in all the culture flasks at start	1·0400	..	1·0120	..
2	Residual sugar	0·3870	..	0·4248	..
3	Glucose consumed	0·6530	..	0·5872	..
4	CO_2 equivalent of glucose consumed	0·9577	..	0·8612	..
5	CO_2 evolved during the combustion of the bacterial residue	0·1340	13·99	0·1224	14·21
6	CO_2 evolved during the experiment	0·2140	22·35	0·1816	21·09
7	CO_2 from the combustion of the filtrate after allowing for residual sugar	0·5776	60·33	0·5194	60·32
8	Total CO_2 accounted for	0·9256	**96·65**	0·8234	**95·62**

It may be seen from the table that in experiment 4 out of 0·6530 grm. of glucose, equivalent to 0·9577 grm. of carbon dioxide utilised by the organism during the course of forty-five days, the carbon dioxide accounted for was 0·9256 grm. or 96·65 per cent of the theoretical value. In experiment five 0·8234 grm. of carbon dioxide has been traced out of 0·8612 grm. carbon dioxide equivalent to 0·5872 grm. glucose fermented in the medium. The results further show that out of the total carbon dioxide equivalent of glucose utilised in the two experiments about 21·22 per cent appeared as free carbon dioxide, fourteen per cent was assimilated by the cells and the balance 64·78 per cent constituted the carbon of the products of fermentation other than carbon dioxide. A major portion of the sugar destroyed thus appears to be converted into by-products such as alcohol, organic acids, mainly, lactic and acetic, and other carbon compounds.

II. NITROGEN

In nature, the nodule organism is always found to grow in the presence of complex nitrogenous compounds, both organic and inorganic, present in the soils, mainly in the form of proteins and nitrates. It is desirable to have a better knowledge regarding the behaviour of the organism towards at least some of these compounds before getting an insight into the nitrogen fixation by it in symbiotic association with the host plant. Experiments were planned therefore to get an idea of a preliminary nature on this aspect of the problem in artificial synthetic Ashby's dextrose media containing peptone and calcium nitrate in the presence and absence of yeast-water.

METHODS

The methods adopted for the determination of amino acids and nitrogen in its various forms in peptone and nitrate cultures are as below :—

(*a*) *Peptone medium*

(*i*) *Amino acids*.—These were estimated in 2 c.c. of culture adopting the formol titration method recommended by Brown [1923] for bacteriological media. The results were expressed as mg. of nitrogen in 100 c.c. of the medium.

(*ii*) *Ammoniacal nitrogen*.—This was determined in suitable aliquots (10 c.c.) of the cultures by the Folin air current method. The ammoniacal nitrogen calculated was then expressed as mg. per 100 c.c. of the culture medium.

(*iii*) *Total nitrogen*.—This was estimated by the usual Kjeldahl method and the results expressed as mg. nitrogen per 100 c.c. of the medium.

(*b*) *Nitrate medium*

In the cultures with calcium nitrate, ammonia, nitric and organic nitrogen were determined in one and the same sample according to the procedure recommended by Davisson and Parsons [1919], taking 25 c.c. of the culture in each case. The results for the various forms of nitrogen were expressed as mg. of nitrogen in 100 c.c. of the culture medium.

Sugar.—This was determined in both peptone and nitrate cultures as before adopting the macro method of Shaffer and Hartman [1920-21].

Experiment 6 : Influence of varying concentrations of glucose on protein attack by the organism

Ashby's medium (pH 7·0) free from sugar and with one per cent peptone formed the basis of this experiment and the various combinations used were as below :—

Culture No. 1. Basic medium without glucose *plus* yeast-water.

Culture No. 2. Basic medium alone.

Culture No. 3. Basic medium *plus* 0·2 per cent glucose.

Culture No. 4. Basic medium *plus* 0·5 per cent glucose.

Culture No. 5. Basic medium *plus* 1·0 per cent glucose.

Culture No. 6. Basic medium *plus* 2·0 per cent glucose.

Two sets of 200-c.c. conical flasks, each containing fifty c.c. of the medium prepared as above, were sterilised and inoculated with one c.c. of a fresh culture of the organism using two flasks for any one combination. Initial analysis of the samples was made for pH, sugar present, ammonia, amino acid and total nitrogen. The flasks were then incubated for a fortnight and analysed for *p*H and other factors as at start. The average results of the analysis conducted in duplicate for the six combinations are incorporated in Table VIII.

TABLE VIII

Influence of glucose on peptone utilisation

Cultures No.	Total N in 100 c.c. culture		Ammoniacal N in 100 c.c.		Amino acid N in 100 c.c.		Sugar		*p*H value	
	At start	At the end of 15 days	At start	At the end of 15 days	At start	At the end of 15 days	Present at start	Utilised at the end of 15 days	Initial	Final (15 days)
	(mg.)	(mg.)	(mg.)	(mg.)	(mg.)	(mg.)	(mg.)	(mg.)		
1	158·4	157·2	Trace	38·90	*Nil*	17·10	*Nil*	*Nil*	7·0	8·1
2	158·4	158·1	,,	55·20	,,	15·30	,,	,,	7·0	7·9
3	158·4	158·3	,,	55·40	,,	14·60	0·192	0·192	7·0	7·9
4	158·4	156·9	,,	46·20	,,	16·80	0·484	0·384	7·0	7·9
5	158·4	157·5	,,	42·30	,,	20·80	0·986	0·544	7·0	6·7
6	158·4	158·1	,,	32·80	,,	22·10	1·943	0·887	7·0	6·5

From the results it may be seen that the ammonia output is considerably greater in cultures containing very little or no sugar than in the other media. The reaction of these cultures also, as it would be expected, were on the alkaline side, (cultures 1 to 4). In the last two media, 5 and 6, with about one per cent and two per cent of sugar respectively, the ammonia evolved was comparatively less than from the rest, though the amounts of sugar consumed in these media were greater. The reactions of these cultures, unlike those of the first four, were slightly acidic, less than *p*H 7·0, indicating thereby the 'protein sparing' action or the economical utilisation of peptone by the organism in presence of sufficient quantities of readily available carbohydrates (one per cent and above). The amount of ammonia produced in culture No. 1 to which yeast-water was added, but no sugar, was much less than in the other media, except No. 6. Probably, the presence of yeast-water tends to shield the protein from being attacked by the organism. The maximum alkaline reaction recorded for this culture might be due to the absence of any sugar and the consequent production of acid to neutralise the ammonia liberated in the medium. Regarding amino acids produced in the various cultures, the deviations observed were small except in the last two media.

Experiment 7: Path of the peptone break-down in one per cent dextrose Ashby's medium in the presence and absence of yeast-water at intervals

This experiment was started with a view to tracing the course of the utilisation of the added nitrogen in relation to a given amount of carbohydrate, one per cent glucose, at various stages of fermentation, incidentally working out a complete nitrogen balance.

Fifty-c.c. lots of Ashby's one per cent dextrose medium containing one per cent peptone were distributed into twelve 200-c.c. conical flasks. After sterilisation the flasks were inoculated each with one c.c. of fresh culture of the organism. A set of another twelve flasks containing Ashby's medium of the same composition and reaction as above with the addition of yeast-water was also included for the study. The analyses of these two sets of cultures, with and without yeast-water, were made immediately after inoculation and also at intervals in duplicate, for residual sugars, total nitrogen—ammonia and amino acid. The results from these two sets of experiments are embodied in Tables IX and X.

TABLE IX

Peptone attack by the organism in presence of yeast-water at intervals

Days of incubation	NH_3-N in 100 c.c. culture (mg.)	Amino acid N in 100 c.c. culture (mg.)	Total N in 100 c.c. culture (mg.)	Glucose initial in 100 c.c. culture (mg.)	Glucose utilised in 100 c.c. culture (mg.)
At start . .	Trace	Trace	154·4	971	..
3 days . .	6·7	31·6	153·8	971	86
6 days . .	14·6	30·2	152·9	971	230
9 days . .	23·4	24·8	153·2	971	328
16 days . .	36·1	22·4	154·1	971	406
21 days . .	27·4	37·9	153·5	971	512

TABLE X

Peptone attack by the organism in absence of yeast-water at intervals

Days of incubation	NH_3-N in 100 c.c. culture (mg.)	Amino acid N in 100 c.c. culture (mg.)	Total N in 100 c.c. culture (mg.)	Glucose initial in 100 c.c. culture (mg.)	Glucose utilised in 100 c.c. culture (mg.)
At start . .	Trace	..	154·9	984	..
3 days . .	9·4	33·3	153·6	984	44
6 days . .	17·9	29·2	153·5	984	181
9 days . .	25·6	26·5	154·3	984	275
16 days . .	39·8	24·1	152·8	984	323
21 days . .	32·5	38·6	154·1	984	408

The results from both the tables show that there was a progressive increase in ammonia produced, followed by a decrease in amino acids up to the 16th day. Subsequently, the amino acid increased with a corresponding fall in ammonia. The ammonia and amino acids produced in the cultures with yeast-water were, however, less than in the pure peptone cultures. These observations again tend to confirm the views expressed already, regarding the 'protein sparing' action of the organism in presence of yeast-water. The organism while consuming more sugar in the yeast-water medium appears to shield the protein in the culture. That the rise in ammonia in all the media is correlated with a drop in the amino acids may be seen also from Figs. 5 and 6. The total nitrogen content of the cultures belonging to both the sets remained practically constant throughout the entire period of the analysis but for the slight and negligible fluctuations here and there. The last two experiments clearly demonstrate that the groundnut nodule organism is capable of attacking peptone and utilising the amino acids formed for its structural purposes with the consequent liberation of ammonia split off intracellularly.

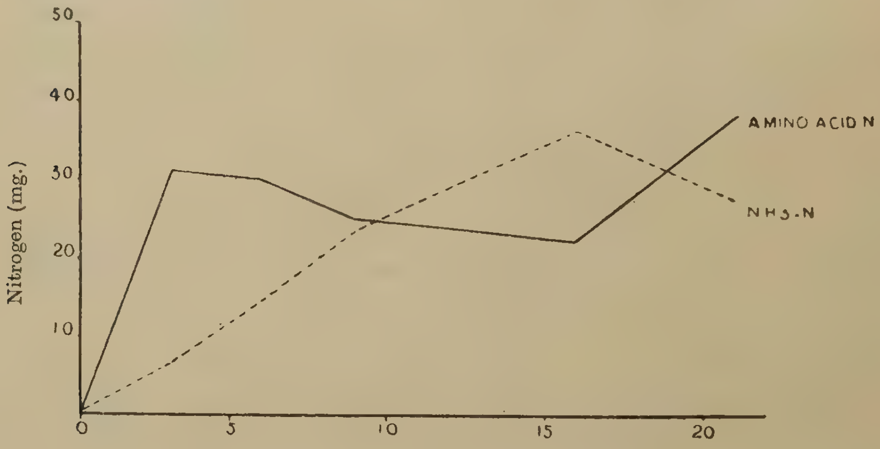


FIG. 5. Peptone attack in Ashby's yeast-water medium

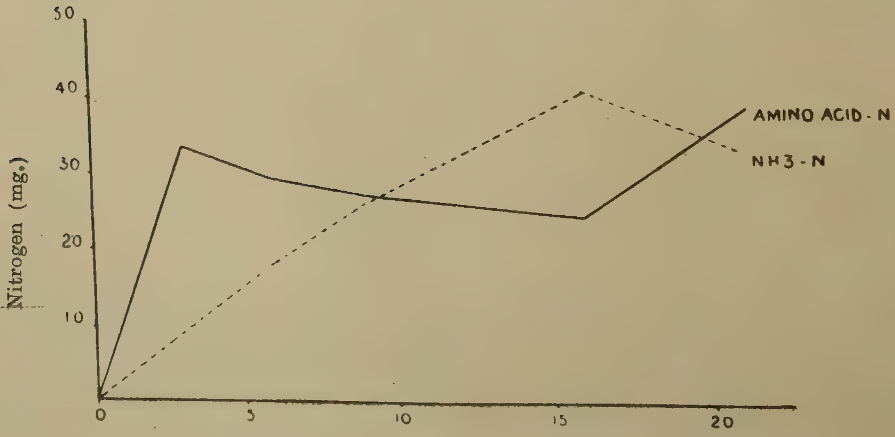


FIG. 6. Peptone attack in Ashby's medium without yeast-water

Attack of nitrate by the organism.—The behaviour of nodule bacteria towards inorganic nitrogenous compounds appears to have not been studied in detail in artificial cultures. The reduction of nitrates in synthetic media has, however, been investigated by a number of workers, especially Hills [1918], Beijerinck [1888], Zipfel [1911], Müller and Stapp [1925] and Leonard [1929]. The views held by these investigators regarding the nature of reduction were of a conflicting nature. Some held that nitrate was reduced to nitrite and thence to ammonia and a few others were of opinion that the reduction stopped at the nitrite stage. No attempt seems to have been made by any of these investigators to work out a complete nitrogen balance of cultures of the organism containing known amounts of nitrates.

It is also a well-known fact that *Rhizobia* make a good growth in pure Ashby's medium even with a trace of nitrate while little or no growth takes place in a culture free from it. The stimulated growth and increased utilisation of glucose noticed in cultures rich in nitrates might, as postulated already (part III), be due either to the nitrogen or oxygen of the nitrate. With a view to determining the probable factor responsible for the increased growth and also to have an idea of the fate of the added nitrate in a culture of the organism, the following experiment was started in Ashby's dextrose medium in the presence and absence of yeast-water :—

Experiment 8: Path of the nitrate break-down in the presence and absence of yeast-water

Fifty-c.c. portions of Ashby's dextrose (one per cent) medium at *p*H 7·0 with and without yeast-water were distributed in 200-c.c. conical flasks sterilised and inoculated, using one c.c. of fresh culture for each flask. Eight flasks were used for the medium with yeast-water and an equal number for the medium with nitrate alone. Two flasks from each set were analysed at intervals for ammonia, organic nitrogen, nitric and nitrous nitrogen and residual sugar. Calcium nitrate was selected for the preparation of the medium as this was found better suited than the other common inorganic nitrates, ammonium, potassium or sodium, for a good growth of the organism as judged by microscopic observation of the cultures of the organism containing these salts.

From the results of the analysis recorded in Tables XI and XII it is rather curious to note that the nitrate rapidly disappeared from the various media till nothing was left in them at the end of a fortnight, without any increase whatsoever in the ammoniacal or organic nitrogen. At no time of the analysis there was detected any ammonia or appreciable organic nitrogen in any of the cultures.

TABLE XI

Path of nitrate break-down and glucose utilisation in the absence of yeast-water in Ashby's medium at intervals

Nature of the culture and days of incubation	Nitrogen in 100 c.c. culture as				Sugar in 100 c.c. of culture (mg.)	N—un-accounted for (mg.)
	Nitric and nitrous-N (mg.)	Organic-N (mg.)	Ammonia-cal-N (mg.)	Total N (mg.)		
3 days, control	134·4	..	..	134·40	956·0	..
Inoculated .	112·0	6·32	..	118·32	898·0	..
Balance .	—22·4	6·32	..	—16·08	—58·0	—16·08
7 days, control	134·4	..	..	134·40	956·0	..
Inoculated .	90·2	7·84	..	98·04	773·5	..
Balance .	—44·2	7·84	..	—36·36	—182·5	—36·36
10 days, control	134·40	..	..	134·40	956·0	..
Inoculated .	43·12	10·08	..	53·20	734·5	..
Balance .	—91·28	10·08	..	—81·20	—221·5	—81·20
15 days, control	134·40	..	..	134·40	956·0	..
Inoculated .	4·72	13·48	..	18·20	605·0	..
Balance .	—129·68	13·48	..	—116·20	—351·0	—116·20

TABLE XII

Path of nitrate break-down and glucose utilisation in presence of yeast-water in Ashby's medium at intervals

Nature of the culture and days of incubation	Nitrogen in 100 c.c. culture as				Sugar in 100 c.c. of culture (mg.)	N—un-accounted for (mg.)
	Nitric and nitrous-N (mg.)	Organic-N (mg.)	Ammoniacal-N (mg.)	Total N (mg.)		
3 days, control	134·4	..	..	134·40	956·0	..
Inoculated .	107·5	6·56	..	114·06	868·0	..
Balance .	—26·9	6·56	..	—20·34	—88·0	—20·34
7 days, control	134·40	..	..	134·40	956·0	..
Inoculated	71·12	9·36	..	80·48	691·0	..
Balance .	—63·28	9·36	..	—53·92	—265·0	—53·92
10 days, control	134·40	..	..	134·40	956·0	..
Inoculated .	27·32	11·96	..	39·28	572·5	..
Balance .	—107·08	11·96	..	—95·12	—383·5	—95·12
15 days, control	134·40	..	..	134·40	956·0	..
Inoculated .	..	14·52	..	14·52	530·0	..
Balance .	—134·40	14·52	..	—119·88	—426·0	—119·88

That there is actually denitrification or reduction of the nitrates, was proved also by the following simple qualitative test. A set of saccharimeter tubes containing Ashby's yeast-water medium with glucose (one per cent) and calcium nitrate was inoculated after sterilisation, each with a loopful of a fresh and rich culture of the organism and incubated at 28°C. for a fortnight. The gases collected at the graduated limbs of the fermentation tubes were measured and absorbed subsequently first with potassium hydroxide and then with alkaline pyrogallol. From the results of the tests conducted in duplicate it was found that carbon dioxide formed one-third of the total volume of gases collected and the rest all nitrogen or oxides of nitrogen. There was absolutely no shrinkage in volume of the residual gases when alkaline pyrogallol was introduced in the tubes, after the absorption of carbon dioxide by potassium hydroxide, indicating thereby the absence of any free oxygen in the gases collected. This experiment offers, therefore, a positive and easy test regarding the decomposition of the added nitrate by the organism mainly for its oxygen with the consequent liberation of nitrogen or the oxides of nitrogen.

Experiment 9: Composition of the bacterial cells—carbon and nitrogen contents

For the purpose of this study mass cultures of the organism were grown in special culture flasks using Ashby's yeast-water-mannite medium. Growths from the flasks were collected at weekly intervals for a month, by scraping with a piece of stiff cardboard attached to a platinum spade. Two flasks were taken out every time the growth was collected for analysis. Care was taken to see that no agar piece was removed from the flask along with the scrapings. The material thus collected from the flask was suspended in distilled water and filtered under suction over a weighed Gooch filter padded with a thick felt of ignited asbestos and a layer of Kiesulguhr. The residue on the filter was then washed a number of times with boiling water to remove any trace of agar in the bacterial mass. The substance was then dried to constant weight and analysed for nitrogen and carbon contents. Two samples were obtained on each occasion, one for nitrogen and the other for carbon estimation. Nitrogen was estimated calorimetrically in the Kjeldahl digest of the bacterial residue and the carbon by the dry combustion process described previously. The results of the analysis and the carbon-nitrogen ratios for the various periods are set forth in Table XIII.

Table XIII

Sample No.	Age of culture (days)	Carbon per cent of dry cells (100°C.)	Nitrogen per cent of dry cells (100°C.)	C : N ratio
1	7	35·20	1·43	24·6
2	14	33·70	1·52	22·2
3	21	36·80	1·81	20·0
4	30	37·50	2·09	19·1

It may be inferred that the nitrogen of the bacterial cells increased with the age of the culture with decreasing carbon-nitrogen ratios. The nitrogen in the cells at the end of one month is about forty-six per cent more than that found at the close of the first week.

Experiment 10

An examination of the enzymes present in the bacterial cells was made qualitatively adopting the general procedure recommended by Waksman and Davidson [1926]. A few preliminary studies on this problem have been made by Biejerinck [1888], Müller and Stapp [1925] and others. No intensive and systematic study has been made on this aspect and it deserves better attention in view of the possible role that some of the enzymes may play in the fixation of atmospheric nitrogen, directly or indirectly in symbiosis with the plant. This being a separate problem in itself, attention is being confined here only to the qualitative detection of the enzymes present in a culture of the organism. For conducting this study, the bacterial mass collected from yeast-water-mannite-agar surface was ground with quartz sand adding a small quantity of glycerol and water. The mass was further centrifuged and the supernatant liquid used for the tests in presence of toluene. The liquid containing the enzymes was preserved by adding sufficient amount of the antiseptic. The results of the tests for the various enzymes are inserted in Table XIV. Controls without enzymes were always run in the presence of toluene.

TABLE XIV

Enzymes of the organism

Enzyme tested for	Substance taken for test	Result
1. Proteolytic enzyme	Gelatin	Positive
2. Zymase	Glucose	Negative
3. Carboxylase	Pyruvic acid	Positive
4. Oxidase	Tincture guaiacum	
5. Peroxidase	Tincture guaiacum and hydrogen peroxide (H_2O_2)	
6. Tyrosinase	Tyrosine	
7. Catalase	Hydrogen peroxide (H_2O_2)	
8. Reducing enzymes	Methylene blue	
9. Urease	Urea	
10. Deaminase	Glycine	
11. Maltase	Maltose	
12. Lactase	Lactose	
13. Invertase	Sucrose	
14. Amylase	Starch	Negative
15. Cytase	Xylan	
16. Lipase	Olive oil	

III. DISCUSSION

The groundnut nodule organism in accordance with the general theory on bacterial metabolism has been found to spare the protein or utilise it economically in presence of sufficient amounts of readily available carbohydrates. The production of amino acids and ammonia in peptone media by the organism may be of great economic importance in the nitrogen nutrition of the host plant. By the conversion of the crude protein matter in and around the roots and nodules of the plantby the organism into easily assimilable forms, mainly amino acids and ammonia, the plant may stand to derive benefit. As a result of this depletion of the protein matter in the soil round the plant by the organism, the non-symbiotic nitrogen fixers like *Azotobacter* may become vigorous and active in mobilising the atmospheric nitrogen and converting it into complex proteins constituting their cellular matter. There was also a definite correlation evinced between the amino acids produced and ammonia formed in peptone cultures of the organism at varying periods. The increase in ammonia in these cultures is generally associated with a corresponding decrease in amino acids. This phenomenon which is in accordance with the theory of Kendall and Walker [1915] probably corresponds to the period of maximum growth of the organism with maximum sugar utilisation and acid formation. During this anabolic process the bacterium may utilise the amino acids for its structural purposes. This active absorption of amino acids will result in their decrease in the surrounding medium followed by an increased production of ammonia, through the katabolism of a portion of the absorbed amino acids by the organism. In the calcium nitrate cultures, the progressive and rapid loss of nitrogen takes place without a corresponding increase either in the organic nitrogen or in the ammoniacal nitrogen. The organism evidently attacks the nitrate mainly for its oxygen necessary for its respiration processes especially in liquid media under partially aerobic conditions. In soils, where similar conditions prevail, it is likely that the organism may act as a denitrifier as in artificial liquid cultures containing nitrates, and immobilise the nitrate nitrogen. The nitrogen thus lost might eventually be recouped by the stimulated activity brought about by the oxygen of the nitrate, provided sufficient amount of carbohydrate is ensured, particularly when the organism is working in symbiosis with its host plant. Again, the presence of some of the important enzymes like deaminase found in a culture of the organism is evidently responsible for the conversion of the crude protein matter in nature into ammonia and amino acids in which forms the plant may derive its nitrogen nutrition. The formation of free amino acids like glycine, asparagine, in the nodules of legumes has been demonstrated by Sani [1910], Parissi and Zannini [1926] and others. The amino acids formed might be due either to the enzymes of the bacteria themselves or of the plant. It has been shown by Virtanen and Hausen [1931, 1, 2] that the plant may utilise amino acids directly. The presence of deaminase detected in a culture of the organism may still further prove to be of great value to the plant in so far as it may bring about the conversion of these free acids into ammonia which is the easiest of all the nitrogen sources to be assimilated by the plant. The role of this enzyme in plant nutrition thus appears to be very important and unique. Similarly, urease and other amidases that may be present in the culture of the organism may as well be expected to prove beneficial to the plant by ammonia production from urea and other similar substances found in nature. It is obvious from these observations that the nodule organism may not only directly fix atmospheric nitrogen in symbiosis with the host plant but also indirectly help it through these enzymes, by conversion of protein, etc., into amino acids and ammonia. The individual role of the different enzymes detected in a culture of the organism deserves, therefore, to be studied in detail.

The increase in the nitrogen content of the old bacterial cells with a low carbon-nitrogen ratios suggests a close correlation between the nitrogen assimilation and the bacteroid or involution stage of the organism. Recent work on this factor by Müller and Stapp [1925], Peiffer [1928] and others, however, does not show any such relationship. The physiological importance of bacteroids in relation to nitrogen fixation is therefore still a matter of speculation and, as it has been pointed out by Fred and his co-workers [1932] in their monograph, has not been satisfactorily explained.

IV. SUMMARY

1. The products detected and estimated in the fermentation of glucose Ashby's medium were (*i*) acetic acid, (*ii*) alcohol, (*iii*) traces of aldehyde, (*iv*) lactic acid, (*v*) tartaric acid, besides carbon dioxide.

2. Most of the carbon assimilated by the organism in dextrose Ashby's nitrate medium has been accounted for. The results show that out of the total carbon in the sugar utilised by the organism, about twenty-one per cent appeared as carbon dioxide, fourteen per cent in the cells, and the balance sixty-five per cent formed the carbon of the by-products other than carbon dioxide.

3. The nitrogen content of the bacterial cells increases with the age of the culture with decreasing carbon-nitrogen ratios.

4. The enzymes tested for and detected in the bacterial cells of the organism in Ashby's mannite-agar medium were, gelatinase, catalase, deaminase, carboxylase, tyrosinase, urease, oxidase and peroxidase, besides various other sugar-splitting enzymes.

5. There is a definite correlation observed between the amino acid produced and ammonia formed in the peptone cultures of the organism. The increase in ammonia in these cultures is generally associated with a corresponding decrease in amino acids.

6. In nitrate cultures, the organism attacks the nitrate without a quantitative corresponding increase in the organic or ammoniacal nitrogen at any period of analysis.

ACKNOWLEDGMENTS

The author wishes to express his thanks to Rao Bahadur B. Viswanath, F.I.C., F.C.S., Director, Imperial Agricultural Research Institute, New Delhi, and formerly Agricultural Chemist to the Government of Madras, and also to Mr. P. D. Karunakar, M.Sc. (U. S. A.), Agricultural Bacteriologist, Agricultural Research Institute, Coimbatore, for their valuable help and advice tendered during the course of this investigation.

REFERENCES

Beijerinck, M. W. (1888). *Bot. Ztg.* **46,** 726-735, 741-750, 757-771, 781-790, 797-804

Brown, J. A. (1923). *J. Bact.* **8,** 244

Davisson, B. S. and Parsons, J. T. (1919). *J. Industr. Engng. Chem.* **11,** 306-311

Dyer, D. C. (1916). *J. Biol. Chem.* **28,** 445

Fred, E. B. ; Baldwin, I. L. and McCoy, E. (1932). *University of Wisconsin Studies in Science* **5,** 1-343

Gortner, R. A. (1916). *Soil Sci.* **2,** 395-440

Hills, T. L. (1918). *J. Agric. Res. (U. S. A.)* **12,** 183-230

Kendall, A. I. and Walker, A. W. (1915). *J. Infect. Dis.* **17,** 442

Leonard, L. T. (1929). *J. Bact.* **17,** 19

Müller, A. and Stapp, C. (1925). *Arb. Biol. Abt. (Anst-Reichsanst)-Berl.*

Parisi, E. and E. Masetti-Zannini, C. (1926). *Staz. Sper. Agr. Ital.* **59,** 207-228

Peiffer, H. (1928). *Zbl. Bakt. (Abt.* 2) **73,** 28-57

Ranganadhan, S. and Norris, R. V. (1927). *J. Ind. Inst. Sci.* **10A** and **B,** 79-97

Russell, E. J. (1932). ' Soil Conditions and Plant Growth ' sixth edition, pp. 1-351

Sani, G. (1910). *R. C. Accad. Lincei 5th Ser. 19 / 20 semestre,* 207-211

Seshadri, T. R. (1933). *Mad. Agric. J.* **21,** 413-421

Shaffer and Hartman (1920-21). *J. Biol. Chem.* **45,** 365

Virtanen, A. I. and Von Hausen, S. (1931, 1). *Biochem. Z.* **232,** 1-14

————(1931,2). *Acta. Chem. Fenn. 4: 1931 Studia Chemi corum Fennicorum Communicata et Relata—1931*

Waksman, S. A. and Davidson, W. C. (1926). ' Enzymes, Properties, Distribution, Methods and Application ', pp. 1-364

Zipfel, A. (1911). *Zbl. Bakt. (Abt. 2)* **32,** 97-137

REVIEW

Applied Mycology and Bacteriology. By L. D. GALLOWAY and R. BURGESS (Leonard Hill, Ltd., London), Pp. ix+186. Price 10*s*.

THE chemist, physicist, engineer or manufacturer is frequently compelled to dabble in problems essentially biological in nature. So long as he is dealing with large organisms he perhaps realises his possibilities and limitations, but when he is faced with a problem concerned with micro-organisms he is, in the words of the authors of this handbook " likely to be appalled at the enormous variety of organisms, the multiplicity of staining methods, and the technical jargon of books intended for those with a biological training. An even worse danger is that he should be over-confident, and lend the support of his learning to statements unacceptable to the expert ". This statement gives the keynote to this small manual.

The book is divided into two parts, the first dealing with fundamental principles and the second with application to specific industries. The classification of fungi is covered in eleven pages, the bacteria in fourteen. There is a page of illustrations of fungi and also of bacteria. Bergey's classification of bacteria is given in brief, and since they are identified largely on their physiologic characteristics the single page of sketches may prove adequate. Fungi, however, are classified on their morphological characteristics, and practically all the fungi illustrated belong to the group Fungi Imperfecti. Adequate illustrations of the other three groups and illustrations of terms such as ' ascus ', ' basidium ', ' sporangium ' and so on used in the text would have been very valuable.

The chapters dealing with apparatus and sterilization, methods of isolation, examinaton, and culturing are not only excellent guides for those not well acquainted with microbiological technique but also may serve as useful references for the trained biologist. The selected list of references should prove especially valuable here. Short chapters on metabolism and control of fungi and bacteria complete Part I.

Part II deals with application to special industries, notably food spoilage, fermentation industries and textiles. The methods in these industries are briefly described, the points at which undesirable organisms may enter are indicated, and the methods which may be adopted for control pointed out. The reader least acquainted with microbiology will probably be the most impressed by the stress laid upon cleanliness and the proper adjustment of moisture and temperature conditions during storage in preference to the use of chemical preservatives. Reasons given for discouraging the use of preservatives in foodstuffs are outlined and are worth enumerating here :—

(1) That nearly all these substances are to some extent harmful to the human system.

(2) That fresh food, kept fresh by cool storage, rapid transit, and cleanliness in handling, is richer in vitamins, and is in all ways preferable to stale or dirty food made to appear fresh by chemical means.

(3) That in most cases modern facilities for refrigeration and rapid transport have made the use of preservatives unnecessary.

The section dealing with agriculture is necessarily brief, and it is stated that parasite control is usually effected by means of chemical poisons. It seems rather unwise to lay so much stress on this fact, for the expensive efforts being made to control plant diseases and pests by methods of cultivation and by development of resistant varieties indicate the faith of the biologist that therein lies ultimate control. The impression is conveyed that the hunt for resistant varieties amongst existing forms is all that can be done, and that the efforts of the plant breeder are vitiated by the fact that many fungal parasites morphologically indistinguishable are really composed of a number of ' physiological strains ' capable of infecting various groups of host varieties, and that resistance to one disease does not necessarily mean resistance to other diseases. The possibility of synthesising resistant varieties is not mentioned, though it has been the basis of the breeding of rust-resistant varieties of wheat and is meeting with success in spite of the fact that the causal organism has been found to exist in numerous different physiological forms.

This small handbook, covering as it does a very wide field, is a highly commendable effort to fill a definite need, and its excellent list of classified selected references is in itself sufficient to justify its use not only by specialists in other sciences who are compelled to look into microbiological problems but also by microbiologists who from time to time have to pay attention to the application of their science to industry. [G. W. P.]

QUARANTINE NOTIFICATION

The following notification (No. F. 46-11/38-A, dated the 17th March 1938), issued by the Government of India in the Department of Education, Health and Lands, is reproduced here for general information :—

In modification of this Department Notification No. F. 116-34-A., dated the 8th April 1937, it is notified for general information that no fee will be charged for consignment of plants and fruits intended for export to countries abroad when the work of inspection and certification is done at Karachi by an officer stationed at that place. A fee of Rs. 20 will be charged for each consignment only when an officer has to be called from outside Karachi to make the examination.

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Periodical Abstracts

Lists of publications and papers on Soil Science published in the Empire Overseas in—

	Price	
	s.	*d.*
1933	1	0
1934	1	0
Soil Research in the British Empire published during 1935	1	0
Lists of Publications relating to Soils and Fertilisers—		
Published monthly, per annum, post free	10	0
Monthly Letters—		
Free to recipients, within the British Empire, of 'Publications relating to Soils and Fertilisers.' Subscription, outside the Empire, per annum	4	0
Recent Developments in Soil Analysis—		
Quarterly Supplement to the above publications. Separate copies each	0	6

Occasional Papers

Technical Communications—		
34. Tropical Soils in relation to Tropical Crops	2	6
Annual Report : For the year 1934-35	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions (by the late Sir J. B. Harrison)	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1931-34	25	0

II. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL HEALTH, VETERINARY RESEARCH LABORATORY, NEW HAW, WEYBRIDGE, SURREY

Abstracting Journal

The Veterinary Bulletin—		
1931. Vol. 1. Quarterly (1st Number, April)	7	6
Annual subscription	20	0
Subsequent volumes. Monthly (1st Number, January)	5	0
Annual subscription (postage paid)	40	0

Indexing Publication

	Price s.	 d.
Index Veterinarius—Four issues a year. First issue April 1933— Annual subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed	100	0

III OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL NUTRITION, ROWETT RESEARCH INSTITUTE, BUCKSBURN. ABERDEEN

Journal

Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)—

Subscription per volume of 4 numbers	42	0
Per single number	13	0

Occasional Papers

Technical Communications—

7. Wheat : Pre-eminence as a Cereal Food, Nutritive Value ; Relation to Health and Disease	1	0

Occasional Communications—

1. The Effect of Climate on the Composition of Pasture Plants.

IV. OBTAINABLE FROM THE IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS PLANT BREEDING INSTITUTE, SCHOOL OF AGRICULTURE, CAMBRIDGE

Journal

Plant Breeding Abstracts—

Quarterly. Annual subscription	15	0
Single copies	5	0

Occasional Papers

Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932 1935. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication of the Imperial Bureaux of Plant Genetics)	10	0
Bibliographical Monographs—		
The Experimental Production of Haploids and Polyploids	5	0
Breeding Resistant Varieties, 1930-33 (Supplement)	2	0
An Outline of Cytological Technique for Plant Breeders	1	

V. Obtainable from the Imperial Bureau of Pastures and Forage Crops, Welsh Plant Breeding Station, Agricultural Buildings, Alexandra Road, Aberystwyth, Wales

Journals

	Price	
	s.	*d.*
Herbage Abstracts—		
Quarterly. Annual subscription	15	0
Single numbers	5	0
Herbage Reviews—		
Subscription is at present—Vol. 1 (1933), Vol. 2 (1934), Vol. 3 (1935), Vol. 4 (1936)—included in that to Herbage Abstracts		

Occasional Papers

Bulletins—		
19. Production of Grass Seed	5	0
20. Insects and Other Pests Injurious to the Production of Seed in Herbage and Forage Crops, H. F. Barnes	2	6
21. The Influence of Climatic Conditions on Type Composition. Nils Sylvén	1	0
22. Technique of Grass Seed Production at Welsh Plant Breeding Station. Gwilym Evans	5	0
23. Production of Legume Seed	5	0
24. Collection of Native Grass Seed in the Great Plains, U. S. A. F. J. Crider and M. M. Hoover	2	0

VI. Obtainable from the Imperial Bureau of Horticulture and Plantation Crops, East Malling Research Station, East Malling, Kent

Journal

Horticultural Abstracts—		
A quarterly abstract publication of current horticultural literature—		
Annual subscription	15	0
Single copy	4	0

Technical Communications

8. Horticultural Aspects of Woolly Aphis Control together with a Survey of the Literature. R. M. Greenslade	2	6

Occasional Papers

3. Annotated Bibliography on Bitter-Pit. 1934	1	6
Other Publications—		
Index to Volumes I—X of the *Journal of Pomology and Horticultural Science*, 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science*. Available from the Bureau	5	0
Old and New Standpoints on Senile Degeneration, 1931. By A. P. C. Bijhouwer	0	6

VII. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL BREEDING AND GENETICS, INSTITUTE OF ANIMAL GENETICS, UNIVERSITY OF EDINBURGH, KING'S BUILDINGS, WEST MAINS ROAD, EDINBURGH

Journal

	Price s.	Price *d.*
Animal Breeding Abstracts (Quarterly). Commencing April, 1933. Annual subscription	15	0

Occasional Papers

	s.	*d.*
Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0

VIII. OBTAINABLE FROM THE IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY (HELMINTHOLOGY), INSTITUTE OF AGRICULTURAL PARASITOLOGY, WINCHES FARM DRIVE, HATFIELD ROAD, ST. ALBANS, HERTS

Journals

	s.	*d.*
Bibliography of Helminthology. For the year 1933—		
Library edition, bound in cloth	10	6
Stiff paper cover only	8	0
Helminthological Abstracts. (Issued in five or six parts per volume, each volume covering the literature of a single year.) Subscription per volume, payable in advance	30	0
Completed volumes bound in cloth	32	0

Occasional Papers

	s.	*d.*
The Effects of some Natural Factors on the Second Ecdysis of Nematode Infective Larvae. By G. Lapage. 25 pp.	4	0
Notes and Memoranda—		
11. Recent Developments in the Control of *Heterodera marioni*. 6 pp	1	6

PUBLICATIONS ISSUED BY THE IMPERIAL INSTITUTE OF ENTOMOLOGY, 41, QUEEN'S GATE, LONDON, S. W. 7

	s.	*d.*
Bulletin of Entomological Research.—Published quarterly and containing original articles on Economic Entomology. Issued post-free. Annual subscription (payable in advance)	30	0

Review of Applied Entomology.—Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series. Series 'A' dealing with insect and other arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin, Series 'B' dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post-free.

	Series 'A'	Series 'B'
	s.	*s.*
Annual subscription (payable in advance)	30	15
Vol. XXIII (1935)	42	21

Zoological Record—Part Insecta.—Published annually about July in each year and containing as complete a record as possible of the literature of the previous year chiefly from the systematic standpoint.

	s.	*d.*
Annual subscription (including postage)	15	6
Report of the Fourth Imperial Entomological Conference, 19—27th September 1935	4	0

Publications obtainable from the Imperial Mycological Institute, Kew, Surrey

Journal

Review of Applied Mycology.—Annual subscription, 12 monthly parts, with

title page and index (post-free)	21	0
Single part	2	0
Title page and index	3	0
Report on the Third Imperial Mycological Conference, 1934	2	0

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian Postage]

1. Agriculture and Live-stock in India

ICAR. 1 A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the Tropics (Established 1931. Published in January, March, May, July, September and November, Prepayable subscription Rs. 6 or 9*s.* 9*d.* per annum. Price per part Rs. 2 or 3*s.* 6*d.*) Volumes I to VII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5. A bi-monthly scientific journal of agriculture and the allied sciences mainly devoted to the publication of the results of original research and field experiments. (Established 1931. Published in February, April, June August, October and December. Prepayable subscription Rs. 15 or 24*s.* per annum. Price per part Rs. 3 or 5*s.* 3*d.*) Volumes I to VII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6. A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931. Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s.* 9*d.* Price per part Rs. 2 or 3*s.* 6*d.*) Volumes I to VII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10·1 No. 1. The Fungi of India, By E. J. Butler, C.I.E., D.Sc., M.B., F.R.S., and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s.*

ICAR. 10·2 No. 2. Life-histories of Indian Microlepidoptera, Second Series : Alucitidæ (Pterophoridæ, Tortricina and Gelechiadæ), By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s.* 6*d.*

ICAR. 10·3 No. 3. The Open Pan System of White-Sugar Manufacture, By R. C. Srivastava, B.Sc. (1935, 2nd edition.) Price Rs. 3-2-0 or 5*s.* 6*d.*

ICAR. 10·4 No. 4. Life-histories of Indian Microlepidoptera ; Cosmopterygidæ to Neopseustidæ, By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S.(1933). Price Rs. 4-8-0 or 7*s.* 6*d.*

ICAR. 10·5 No. 5. The Bombay Grasses, By E. J. Blatter, S. J., Ph. D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. (1935). Price Rs. 20-12-0 or 32*s.* 6*d.*

ICAR. 10·6 No. 6. Helminth Parasites of the Domesticated Animals in India, By G. D. Bhalerao, M.Sc. (1935). Price Rs. 7-12-0 or 13*s.* 3*d.*

ICAR. 10·7	No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng. and the Isolation of Types Resistant to the Disease, By W. McRae, M.A., D.Sc. (Edin.), F.L.S. and F.J.F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s*. 3*d*.
ICAR. 10·8	No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy, By C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s*. 9*d*.
ICAR. 10·9	No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah-Shell Oil Storage and Distributing Company of India, Ltd., By C. P. G. Wade. (1935). Price Rs. 3-14-0 or 6*s*. 6*d*.
ICAR. 10·10	No. 10. The Spotted Bollworms of Cotton in South Gujarat, By B. P. Deshpande and N. T. Nadkarny, B.Ag. (1936). Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 10·11	No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus muscles and the formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations, By. H. N. Chelva Ayyangar, G.M.V.C. (1937), Price Rs. 4-10-0 or 7*s*. 9*d*.
ICAR. 10·12	No. 12. The Fungi of India, Supplement I. By B. B. Mundkur. (*In the Press*)

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8·1	No. 1. List of Publications on Indian Entomology, 1930, By the Imperial Entomologist, Pusa. (1934). Price As. 14 or 1*s*. 6*d*.
ICAR. 8·2	No. 2. List of Publications on Indian Entomology, 1931, By the Imperial Entomologist, Pusa. (1934). Price As. 8 or 10*d*.
ICAR. 8·3	No. 3. List of Publications on Indian Entomology, 1932, By the Imperial Entomologist, Pusa. (1934). Price As. 12 or 1*s*. 3*d*.
ICAR. 8·4	No. 4. Host Plant Index of Indo-Ceylonese Coccidae, By S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. (1934), Price Rs. 1-10-0 or 2*s*. 9*d*.
ICAR. 8·5	No. 5. List of Publications on Indian Entomology, 1933, compiled by the Imperial Entomologist, Pusa. (1935). Price As. 9 or 1*s*.
ICAR. 8·6	No. 6. Bee-keeping, By C. C. Ghosh, B.A., F.E.S. (3rd Edition.) (1936). Price Rs. 1-14-0 or 3*s*. 3*d*.
ICAR. 8·7	No. 7. List of Publications on Indian Entomology, 1934, compiled by the Imperial Entomologist, Pusa. (1935). Price Rs. 1-2-0 or 2*s*.
ICAR. 8·8	No. 8. Selected Clinical Articles, Part I, By G. K. Sharma, G.P.V.C. and R. L. Kaura, B.V.Sc., M.R.C.V.S. (1936). Price As. 8 or 10*d*.
ICAR. 8·9	No. 9. Statistical Methods and their Application to Agronomy; A bibliography, By. K. K. Guha Roy. (1936). Price Rs. 2-2-0 or 4*s*.
ICAR. 8·10	No. 10. Diseases of Sugarcane and Methods for their Control, By. L. S. Subramaniam. (1936). Price Re. 1, As. 14 or 3*s*. 3*d*.
ICAR. 8·11	No. 11. Tables of Standard Errors of Mendelian Ratios, compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell) and P. Krishna Rao, L.Ag. (1936). Price As. 12 or 1s. 3*d*.
ICAR. 8·12	No. 12. List of Publications on the Botany of Indian Crops, Part II, for the period 1928-32, By R. D. Bose. (1936). Price Rs. 3-6-0 or 6*s*. 9*d*.

ICAR. 8·13	No. 13. Two New Statistical Tables based upon Fisher's '*t*', By M. Vaidyanathan. (1936). Price As. 6 or 8*d*.
ICAR. 8·14	No. 14. List of Publications on Indian Entomology (1935), compiled by the Imperial Entomologist, Pusa. (1937). Price Re. 1-4-0 or 2*s*.
ICAR. 8·15	No. 15. Selected Clinical Articles, Part 11, By G. K. Sharma, G.P.V.C., R. L. Kaura, B.V.Sc., M.R.C.V.S., S. Ganapathy Iyer, G.M.V.C., G. S. Khan, B.Sc. and S. Mangrulkar, M.Sc., M.R.C.V.S., D.T.V.M. (EDIN.) (1937). Price Re. 1-4-0 or 2*s*.
ICAR. 8·16	No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders, by P. E. Lander, M.A., D.Sc., F.I.C., I.A.S. (1937). Price Rs. 3-14 or 6*s*. 9*d*.
ICAR. 8·17	No. 17. A Brief Survey of some of the Important Breeds of Cattle in India, by Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S., F.N.I. (1938). Price Rs. 2 or 3*s*. 6*d*.
ICAR. 8·18	No. 18. Milk Records of Cattle in Approved Dairy Farms in India, by K. P. R. Kartha, B. A. (*In the Press.*)
ICAR. 8·19	No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province, by Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.) F.N.I. and H. N. Batra, B.Sc., Assoc. I. A. R. I. (*In the Press.*)
ICAR. 8·20.	No. 20. Report on an Enquiry into the Cultivation of Cloves in India, By A. K. Yegna Narayana Aiyar. (*In press*).
ICAR. 8·21	No. 21. Investigations on the Cold Storage of Mangoes, By G. S. Cheems, D.Sc., I.A.S., D. V. Karmarkar, M.Sc., Ph.D., A.I.I.Sc. and B. M. Joshi M.Sc. (*In Press.*)

6. Annual Reports of the Imperial Council of Agricultural Research

ICAR. 12·31	Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.
ICAR. 12·32	Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.
ICAR. 12·33	Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of Stock.)
ICAR. 12·34	Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Rs. 1-8-0 or 2*s*. 6*d*.
ICAR. 12·35	Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.
ICAR. 12·36	Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.
ICAR. 12·37	Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Re. 1-2-0 or 2*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9·29	Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock.)
ICAR. 9·31	Review of Agricultural Operations in India, 1929-31. Price Rs. 5 or 8*s*. 3*d*.
ICAR. 9·33	Review of Agricultural Operations in India, 1931-33. Price Rs. 5-12-0 or 9*s*. 6*d*.

	Agriculture and Animal Husbandry in India, 1933-34 and 1934-35—
ICAR. 13-1-35	Part I.—Crop Production. Price Rs. 4-14-0 or 8*s.*
ICAR. .3-2-35	Part II.—Animal Husbandry. Price Re. 1 or 1*s.* 9*d.*
ICAR. 13·36	Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10 or 7*s.* 9*d.*

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2	Proceedings of the First Meeting of the Animal Husbandry wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s.* 6*d.*
ICAR. 3	Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s.* 9*d.*

9. Miscellaneous Publications

VRI. 1	A Description of the Imperial Institute of Veterinary Research, Muktesar and its Sub-station, the Imperial Veterinary Serum Institute, Izatnagar, By F. Ware, F.R.C.V.S. Price Re. 1-4-0 or 2*s.*
ARI. 7. 187	The Production of Cigarette Tobacco by Flue-curing, By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S., and Kashi Ram. *Imp. Inst. Agri. Res., Pusa Bull.* No. 187. Reprinted (1935). Price Re. 1 or 1*s.* 9*d.*
ICAR. 16	A Handbook of Statistics for Use in Plant Breeding and Agricultural Problems, By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s.* 3*d.*
ICAR. 7	Report on the Work of the Imperial Council of Agricultural Research in Applying Sciences to Crop Production in India, By Sir John Russell, D.Sc., F.R.S. Price Re. 1-14 or 3*s.* 3*d.*
ICAR. 18	Report on the Development of the Cattle and Dairy Industries of India, By Norman C. Wright, M.A., D.Sc., Ph.D. Price Re. 1-8-0 or 2*s.* 6*d.*

Copies of the above publications can be had from :—

The Manager of Publications, Civil Lines, Delhi and from any of the Agents, a list of whom will be found on the inside page of the front cover.

Purchasers not residing in Asia, Africa and Australia should apply to the High Commissioner for India, India House, Aldwych, London. Prices include Indian postage and packing.

Note.—When indenting please give only the symbol preceding the name of the publication.

GIPD—S3—1031 IC of AR—25-6-38—800.

ORIGINAL ARTICLES

STUDIES IN INDIAN FIBRE PLANTS

NO. 6. PHYLLODY AND SOME OTHER ABNORMALITIES IN THE FLOWER OF SUNN-HEMP

BY

R. D. BOSE, B.Sc.

Superintendent, Botanical Sub-Station, Pusa

AND

S. D. MISRA, M.Sc.

Post-graduate Student in Botany, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 28th July 1937)

(With Plates XVI and XVII)

I. INTRODUCTION

MORPHOLOGICAL abnormalities are often observed in plants, but their value in facilitating the correct interpretation of morphological phenomena is not always realised. Moquin-Tandon [1841] believed " that such anomalies are particular modifications which can be brought under common, simple and exact principles which are themselves but corollaries of the most general laws of organization ". Worsdell [1915] expressed the firm opinion " that malformations are often of great value for solving morphological problems."

The occurrence of abnormal organs in plants sometimes helps considerably in the determination of their homologies and is a subject which deserves more than passing attention.

A number of floral abnormalities in sunn-hemp (*Crotalaria juncea* L.) have been observed at Pusa in the course of varietal studies. These abnormalities are mainly due to phyllody of the flowers but in some cases proliferation, adhesion, or fasciation of certain floral structures is also found. It is the purpose of this paper to describe briefly all the kinds of abnormal flowers observed at Pusa in 1935 and 1936.

Phyllody may be defined as the condition in which all or some of the floral whorls are transformed into leaf-like organs or have a tendency to become leafy. Phylloid flowers generally do not set seed and their occurrence in large numbers is liable to reduce the yield of affected crops to an appreciable extent. Penzig [1921-22] has reported that the transformation of carpels or stamens into leaves is a very common phenomenon in the Leguminosæ.

Roy [1931] has published a note on the occurrence of sepaloidy in sesamum which in all probability is nothing but phyllody.

Pal and Pushkar Nath [1935] have described the incidence of phyllody at Pusa in sesamum and observed the transformation of all floral parts, except the stamens, into leaf-like structures. They found it possible to transmit the phylloid condition by grafting normal scions on phylloid stocks and *vice versa*, and suggest that phyllody in sesamum is caused by a virus.

Recently, Rhind, Odell and Thet Su [1937] have published another paper on phyllody of sesamum in Burma and have shown that the disease is not transmitted through the seed and that early sowing brings about a high percentage of phylloid plants. They also record higher mineral metabolism of diseased plants.

In view of the fact that a great deal of virus disease has been observed in the strains of sunn-hemp grown at Pusa, during the past two years, it appears quite possible that the phyllody described in the present paper may be occasioned by some particular form of virus. This view is supported by the result of certain grafting experiments described later.

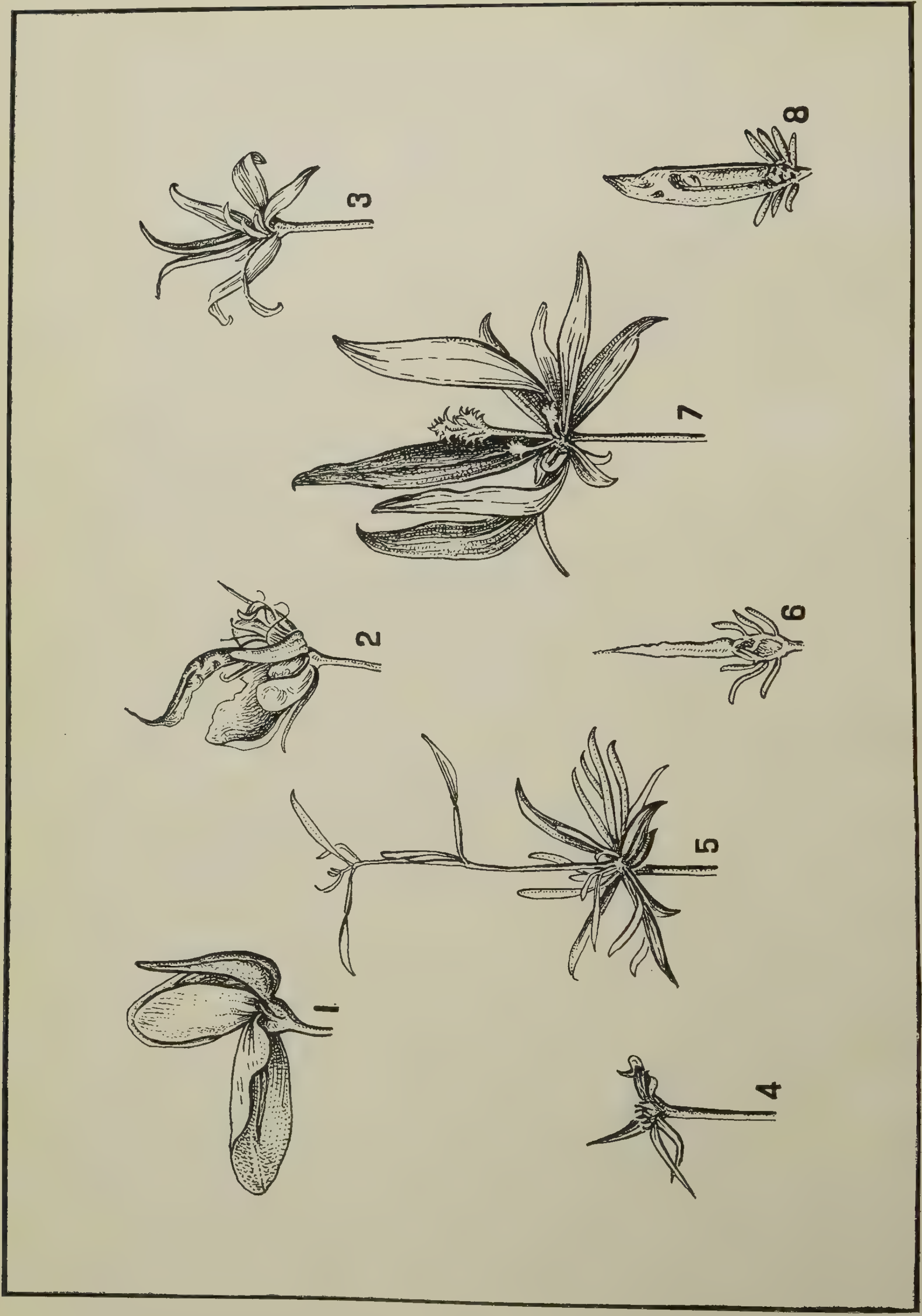
II. MATERIAL

Plants with phylloid flowers were observed at Pusa in 1935 in seven strains of sunn-hemp. The percentage of such plants to those with normal flowers range from 0·05 to 6·61 as is detailed below :—

Percentage of plants bearing phylloid flowers to those having normal flowers in some strains of sunn-hemp

Strain	Number of plants bearing		Percentage of plants showing phyllody
	Phylloid flowers	Normal flowers	
Bombay 11(*a*)-2	1	212	0·47
Bombay 11(*b*)-2	1	136	0·73
Bombay 21-1	8	113	6·61
Sakrand 1	2	148	1·34
Dacca 25	1	71	1·39
Dacca 26	2	56	3·45
Pusa local	8	15800	0·05

In the young stages no difference was observed between the normal plants and those which later developed phylloid flowers. The symptoms of abnormality manifested themselves only in the flowering stage when one or more of the floral organs were transformed into leaf-like structures ; this was usually accompanied by abnormally abundant branching.



Phylloid and other abnormal flowers in sunn-hemp

III. Morphology

The normal flowers in sunn-hemp are large, papilionaceous (Plate XVI, fig. 1), and are borne on erect, terminal and lateral 12-20 flowered racemes, about 25 to 30 cm. in length ; pedicels about 3 to 6 mm. long, pubescent ; bracts minute ; linear-subulate ; bracteoles 2, beneath the calyx, minute ; *calyx*—yellowish-green, 18 mm. long, clothed with fulvous hairs ; teeth linear—lanceolate, very deep.

Corolla—papilionaceous, bright yellow with or without red splashes on the dorsal side of the standard, slightly inserted ; standard—ovate-oblong, sub-acute, shortly clawed ; wings—obovate, shorter than the standard ; keel—broad, equalling the wings, its petals joined down the back, much incurved, distinctly beaked. *Stamens*—monadelphous ; anthers—dimorphous. *Ovary*—sessile, multi-ovulate ; style—long, abruptly incurved at the base, more or less bearded upwards ; stigma—minute, oblique.

The affected plants bear flowers wherein some or all the floral whorls are transformed into leaf-like structures showing different grades of development. The same raceme usually bears flowers with different degrees of transformation, normal flowers being invariably absent. In no case was a plant observed to bear normal flowers in some branches and phylloid flowers on other branches. The common types of abnormal flowers observed during the course of the present study are shown in Plate XVI, figs. 2-8 and their characteristic differences are briefly described below :—

Class I (Plate XVI, fig. 2)

This type of phylloid flower shows the nearest approach to the normal flower ; in spite of the presence of all the floral organs, though in a modified form, it is completely sterile and in this respect it exactly resembles the more advanced conditions of phyllody (Plate XVI, figs. 3-8).

Calyx.—The five sepals form a bilabiate calyx and are connate at the base but are green in colour and are less hairy than the normal sepals. They have a leafy appearance and the internal tissues resemble those of a normal leaf more or less in structure.

Corolla.—The five petals are green and are more or less free. The innermost petals do not form the keel and are not connate at the margins. They are somewhat beaked. The alae are obovate in form and are intermediate in size between the innermost petals and the standard which is fairly large, ovate, and has a crumpled leaf-like surface.

Andrœcium.—Ten free stamens are present and are green in colour. The anthers, as usual, are dimorphic, the short versatile forms alternating with the long basifixed ones. The loculi of the anthers do not contain any pollen.

Gynœcium.—The ovary is very much enlarged, about two or three times the normal size and seems to be formed by the infolding of a green crumpled leaf (Plate XVII, fig. A-2). The style is greatly reduced and there is no stigma.

Class II

Here the other details of the flower are like those described under class I but the ovules also have become leafy in structure.

Class III (Plate XVII, fig. A-3)

Calyx.—The sepals are free and not connate as in the normal flower and are leaf-like in form and internal structure. They are green in colour. The venation has become multicostate and reticulate; the middle vein is very prominent.

Corolla.—The corolla is very much reduced. The five petals are free and green and leafy in structure. The standard is the largest in size but it has a pointed apex. The wings are smaller and also pointed, whereas the innermost petals are beaked.

Andrœcium.—This whorl shows a fairly advanced stage of phyllody. Five of the ten stamens have become enlarged and leaf-like in form and internal structure. They alternate with five green but very much reduced stamens which have basifixed anthers. The leafy stamens bear small buds in their axils.

Gynœcium.—The carpels have been completely transformed into leafy structures and do not show differentiation into styles, stigmas or ovules.

Class IV (Plate XVI, fig. 4)

Calyx.—Five small sepals which are free and leafy in structure can be clearly recognised.

Corolla, *Andrœcium* and *Gynœcium*	The corolla, andrœcium and gynœcium have been reduced in size and structure, and are replaced by small, green buds covered with hairy scales.

Class V

Other details as in the flower of class IV, but the leafy stamens bear small buds at their axils, and ovules are absent.

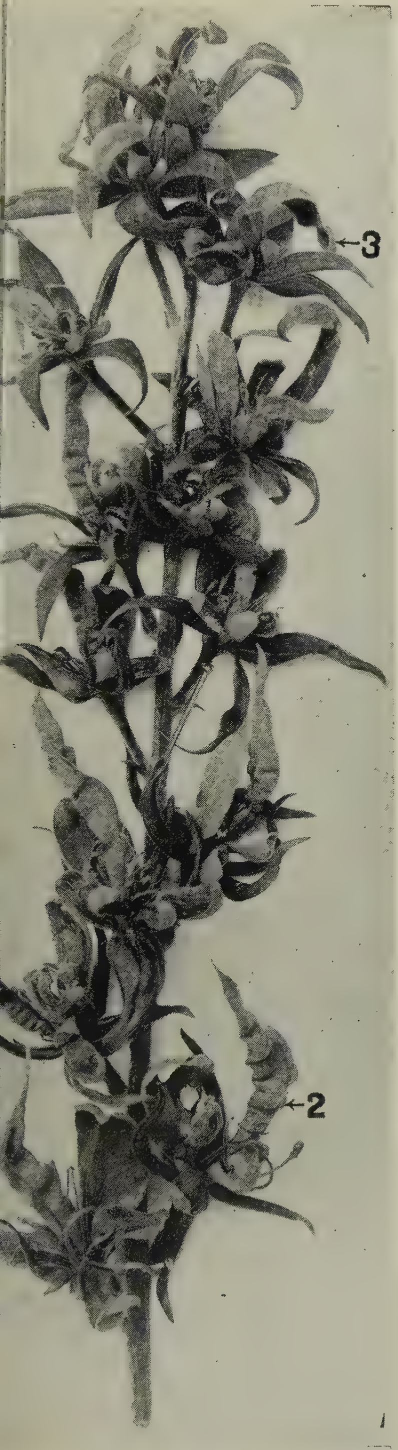
Class VI (Plate XVI, fig. 5)

Calyx.—The five leafy sepals are borne on small stalks but otherwise they resemble the calyx described for Plate XVI, fig. 3.

Corolla.—As for Plate XVI, fig. 3.

Andrœcium.—Five stamens have been transformed into short vegetative shoots which alternate with the other five leafy stamens.

Gynœcium.—No pistil can be recognised but a vegetative shoot, two to ten centimeters in length, is given out from the centre of the flower. This is apparently a case of proliferation.



A. Phylloid flowers in sunn-hemp

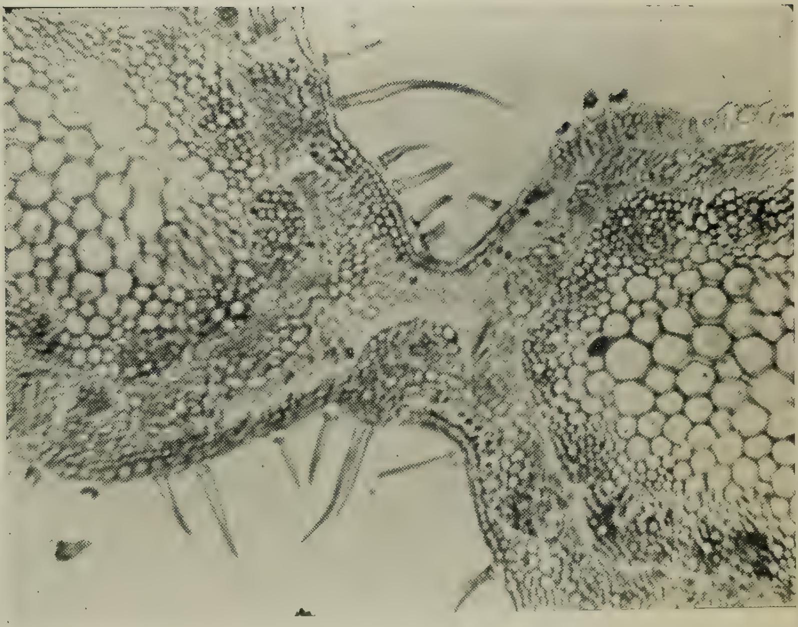


Fig. B. Photomicrograph depicting adherence of the vegetative shoot formed by a transformed stamen to the central vegetative shoot developed from the transformed pistil

Class VII

As in class VI, but in this case the ovary has also been transformed into a floral shoot bearing small phylloid flowers.

Class VIII (Plate XVI, fig. 6)

Calyx, *Corolla* and *Andrœcium*	All these floral parts are greatly reduced in flowers of this kind and look like green scaly leaves.

Gynœcium.—The ovary is quite prominent and the style is green and cylindrical in structure ; the stigma is not developed. The ovules are leafy.

Class IX (Plate XVI, fig. 7)

Calyx.—The sepals are free and have small stalks. They resemble the sepals of flower 5 but are somewhat larger and broader.

Corolla.—The petals are also free and have small stalks. They are larger and broader than the petals of the flower in Plate XVI, fig. 5.

Andrœcium.—The stamens in this flower are characteristically different from those described in the other types of flowers. Five of them are rather large, about 4 to 5 cm. in length and are leaf-like and stalked. They alternate with the remaining five stamens which have been modified into small floral shoots bearing tiny phylloid flowers.

Gynœcium.—This has also been transformed into a floral shoot bearing tiny phylloid flowers. This shoot, however, is about twice or three times the size of the floral shoot of the transformed stamens described above.

Class X

The flowers are almost similar to those in class IX but some of the vegetative shoots formed by the transformation of the stamens show an adherence to the central vegetative shoot which represents the transformed pistil (Plate XVII, fig. B).

Class XI (Plate XVI, fig. 8)

Calyx, *Corolla* and *Andrœcium*	These whorls have been reduced to scaly leaves, as in the flower in Plate XVI, fig. 6 (class VIII) and are also epigynous.

Gynœcium.—The carpel differs from that in the flower in Plate XVI, fig. 6 in being rather flat and more leaf-like in form.

Class XII

As above, but the carpel is rather flat and more leaf-like in appearance.

The principal types of abnormal flowers have been described above. Some account about proliferation, adhesion and fasciation observed in a few flowers are given below.

IV. Proliferation

The production of terminal or lateral leaf buds in a flower is termed proliferation. This phenomenon also has been observed in some abnormal flowers of sunn-hemp. The condition is shown in Plate XVI, fig. 5.

V. Adherence

The flower condition described under class X shows adherence between one of the vegetative shoots, formed by the transformation of the stamens and the transformed pistil.

The enlarged microphotograph (Plate XVII, fig. B) is of a transverse section taken through the region which shows an adherence of the phylloid stamen to the central vegetative shoot. The occurrence of this type of flower is very rare in sunn-hemp.

VI. Fasciation

Fasciation both of the stem and the inflorescence-axis has been reported by Singh [1930] who has cited a case in which the flattening of the axis has taken place and the inflorescence has become so condensed that the bracts and other peduncular leaves appear to be much crowded together; the main axis has coiled up like a watch spring but the flowers themselves do not present any peculiarity and are normal in every way.

A similar plant was observed at Pusa in 1937 in the local sunn-hemp in which the main stem was flattened into a band about 3 to 4 cm. broad and the inflorescence was very much reduced.

VII. Grafting experiments

In order to determine whether the phylloid condition described above was due to virus, cleft grafting was performed in ten pairs of plants in August 1936. Each pair consisted of a normal and a phylloid plant, which were reciprocally grafted as described by Pal and Pushkar Nath [1935]. The top of the healthy plant was grafted on to the lower part of the affected plant and *vice versa*. The grafted plants were staked and covered with muslin bags. Fourteen grafts were successful and at the end of the fifth week after grafting, it was observed that phylloid flowers were developed on all the new branches produced by the originally healthy stock, as well as on the normal scions grafted on affected plants. The remaining six grafts were damaged by heavy rains and strong winds in September.

Although the evidence secured is based only on a small number of grafting experiments, the facts suggest that phyllody in sunn-hemp may also be caused by a virus as has been reported by Pal and Pushkar Nath [1935] in the case of sesamum.

VIII. Summary

Phylloid flowers in sunn-hemp have been observed at Pusa and show the transformation of some or all floral whorls into greenish leaf-like structures. Twelve abnormal types of phylloid flowers have been recognised and are briefly described ; all of these cause complete sterility of the plant. Two or more abnormal types of flowers may be developed on the same floral axis but the same plant does not bear normal flowers on some branches and phylloid flowers on others.

Proliferation of parts has been observed in some phylloid flowers. Adherence of vegetative shoots formed by the transformed stamen and the transformed carpel has also been observed. A case of fasciation was also observed in 1937 in the local sunn-hemp.

That phyllody in sunn-hemp may be due to a virus is suggested by the fact that the condition was transmitted by grafting normal scions on phylloid stocks and *vice versa*.

We are indebted to Dr. B. P. Pal, Imperial Economic Botanist, New Delhi, for critically reading through the manuscript.

REFERENCES

Moquin, Tandon (1841). Cited from Worsdell's 'Principles of Plant Teratology,' 1915-16, p. 7

Pal, B. P. and Pushkar Nath (1935). *Ind. J. Agric. Sci.* **5**, 517-522

Penzig, O. (1921-1922). 'Handbuch der Pflanzen Teratologie' 3rd edition

Rhind, D. ; Odell, F. D. and Thet Su, U. (1937). *Ind. J. Agric. Sci.* **7**, 823-840

Roy, S. C. (1931). *Agric. & Livestock in Ind.* **1**, 282-285

Singh, T. C. N. (1930). *J. Ind. Bot. Soc.* **9**, 250

Worsdell, W. C. (1915 & 1916). 'The Principles of Plant Teratology'. London, Ray Society

A NOTE ON THE OCCURRENCE OF CHLOROPHYLL DEFICIENCY IN *GOSSYPIUM ARBOREUM*

BY

J. B. HUTCHINSON

AND

BHOLA NATH

Institute of Plant Industry, Indore, Central India

(Received for publication on 17th March 1938)

Introduction

The occurrence of chlorophyll deficiency in cotton has been recorded by Harland [1932, 1934] in the New World species. The character was first observed to occur in the F_2 generation of the interspecific cross *G. barbadense* × *G. hirsutum*, and showed itself in a graded series from yellow (grade 1) to light green (grade 8), the latter being quite distinct from the normal full green (grade 9). From the higher grade deficients, Harland was able to establish a viable chlorophyll-deficient strain in which, although the cotyledons were almost devoid of chlorophyll, the adult plant was normal green.

Harland showed that there are two factor pairs which he called $\mathbf{C^{ha}}$ $\mathbf{C^{hb}}$, for green distributed in *G. barbadense* and *G. hirsutum* respectively.

Chlorophyll-deficients in Old World cottons in both *G. arboreum* and *G. herbaceum* were obtained by Ramanatha Ayyar and Balasubramanyan [1937] as a result of exposure of seeds to X-rays. The present note deals with the occurrence and behaviour of chlorophyll deficiency in Malvi cotton, *G. arboreum* L. var. *neglectum*, forma *bengalensis*.

Material

The Malvi chlorophyll-deficient was noticed in 1936 in some F_2 familie of the cross Malvi 9 (*G. arboreum* var. *neglectum*, forma *bengalensis*) × A7 (a strain of *G. arboreum* var. *cernuum*). Both parental strains were established lines which had been selfed continuously for a number of generations. The cotyledons of the chlorophyll-deficient segregates ranged from bright yellow to pale yellow, and pale yellow with a faint diffused tinge of green. The greenest of the chlorophyll-deficients of Malvi was less green than Harland's grade 3. The deficient plants failed to survive the cotyledonary stage, the seedling dying soon after the reserve food materials were exhausted. Repeated attempts to grow the deficients in pot culture proved fruitless.

The deficient seedlings were frequently slow in germinating.

Eighteen F_2 progenies were grown. Data are summarised in Table I.

TABLE I

Segregation of chlorophyll deficiency in F_2 of Malvi 9×A7

Heterozygous										
Progeny . .	583	584	586	589	592	593	633	635	636	Total
Green . .	44	55	46	90	49	90	108	59	116	657
Chlorophyll deficent	15	17	11	29	15	23	28	25	39	202
Total . .	59	72	57	119	64	113	136	84	155	859
χ^2(3 : 1) . .	0·01	0·07	0·99	0·03	0·08	1·30	1·41	1·02	0·00	1·01
Homozygous green										
Progeny . .	582	585	587	588	590	591	631	632	634	Total
Total green .	69	41	29	78	15	119	115	123	122	711

Half the families bred true to green, and half gave a very close fit to 3 green : 1 deficient.

Fourteen F_3 progenies were raised in the 1937-38 season. Their behaviour is given in Table II.

TABLE II

Segregation of chlorophyll deficiency in F_3 of Malvi 9×A7

Heterozygous												
Progeny . . .	692	693	694	695	696	697	699	701	702	703	704	Total
Green . . .	56	36	28	22	33	16	20	13	29	25	26	304
Chlorophyll deficient .	8	4	4	7	10	4	4	8	9	9	3	70
Total .	64	40	32	29	43	20	24	21	38	34	29	374
χ^2 (3 : 1) . . .	5·33	4·80	2·67	0·01	0·07	0·27	0·89	1·92	0·04	0·04	3·32	7·86
Homozygous green												
Progeny . . .	698	700	705	Total								
Total green .	39	29	45	113								

The chlorophyll-deficient class was much below expectation in progenies 692, 693, and 704, suggesting that under certain conditions it may be of low viability. The single factor difference is established, however, and the ratio of homozygous to heterozygous progenies is also close to expectation.

The A7 parent was also parent of 111 other F_2 progenies, which gave greens only. It must therefore have been the Malvi parent that was heterozygous for the deficiency. The heterozygous green Malvi 9 parent occurred in the progeny rows grown by the Plant Breeding Section in the season 1934-35. Since chlorophyll deficiency was not observed by the Plant Breeding Section in the ancestral rows, it is most probable that the plant became heterozygous for green by mutation. The original heterozygote as well as those seen in later generations were indistinguishable from the homozygous green, thus showing complete dominance of green over deficient.

SUMMARY

A chlorophyll-deficient seedling type is described which appeared in a cross between Malvi 9 and a *cernuum* type. Chlorophyll-deficient is shown to be a simple Mendelian recessive to green. No symbol is given to the gene, pending tests of homology with Ramanathan and Balasubramanyan's [1937] types. The origin of the gene is traced to mutation in the Malvi 9 parent.

REFERENCES

Harland, S. C. (1932). *J. Gen.* **25**, 271

——————— (1934). *J. Gen.* **29**, 181

Ramanatha Ayyar, V. and Balasubramanyan, R. (1937). *I. C. C. C. Proc. 1st Conf. Sci. Res. Workers on Cotton in India, Bombay* (*In Press*)

A NOTE ON SEED-SETTING AND SEED-GERMINATION IN CERTAIN SUGARCANES*

BY

N. L. DUTT, M.Sc.

Second Cane-Breeding Officer

M. K. KRISHNASWAMI, M.A.

AND

K. S. SUBBA RAO, B.A.

Imperial Sugarcane Breeding Station, Coimbatore

(Received for publication on 26th August 1937)

(With Plate XVIII)

I. Introduction

In the breeding of the thick canes for India, one of the problems which has engaged the attention of the writers during the last ten years is the improvement of germination of the thick cane seeds. The growing needs of the sugar industry and the demand for high-yielding, disease-resistant varieties has necessitated the utilization of a wide range of parents. Some of the parents chosen were, therefore, of the hardy type, a number of them containing the blood of two or three of the following species of *Saccharum* :—*S. officinarum*, *S. barberi*, and *S. spontaneum*. As good seed-germination is a desideratum in sugarcane breeding, a number of varieties and seedlings have been tested to ascertain their value as breeding material.

II. Material and methods

The seed† employed in these experiments was collected from unbagged inflorescences, as previous experience at the station had shown [Barber, 1916 ; Venkatraman, 1925] that enclosing the inflorescence in a cage adversely affects seed-setting. For preliminary seed experiments the fuzz or fluff used was taken from what are called ' G. Cs.' (General Collections), that is, from unprotected arrows in the open. In such cases, therefore, only the female parent is known. These General Collection sowings have been quite useful because by growing a hundred seedlings from each lot in the field, a good indication is obtained of the type of seedlings to be expected from the particular female parent. The method for sowing seeds [Barber, 1916] was the one which has been in vogue at the station since its inception.

---

* Paper presented at the Indian Science Congress, Hyderabad, January 1937.

† By seed in this note is meant the unthreshed caryopsis.

III. Experiments

(*a*) *Seed treatment*

Attempts were made to treat the seed before sowing with a view to see if it would improve the percentage of germination. The treatments were :—(1) Soaking in water for fifteen hours before sowing ; (2) soaking in concentrated sulphuric acid for five minutes and thoroughly washing before sowing ; (3) soaking in 0·1 per cent ortho-phosphoric acid for fifteen hours before sowing ; (4) soil-fluff mixture ; for this treatment the fluff was mixed with an equal quantity of seed-pan mixture and spread over the pan, the pan being watered in the usual manner. In the soil-fluff mixture the germinations were better than the other treatments but not better than the control (Table VI).

The seed of the varieties used in the above experiments was also sown twenty-seven and forty-seven days after the date of collection to see if desiccation after collection would improve germination or, in other words, if there is any after-ripening in sugarcane seed. In all the above treatments, the seed sown twenty-seven and forty-seven days after collection gave less germination than the control.

(*b*) *Seed-germination in different varieties*

Though for a number of experiments (Table II) equally weighed quantities (3 grammes per seed-pan) were sown, for bulk sowings (Table I) which involved as many as one thousand pans each year, a handful of fuzz as judged by trained labour was sown. The averages given in Table I are from such bulk sowings. For certain varieties the data presented are for seven or eight seasons. It will be seen from the same table that varieties like POJ 2364, POJ 2878 (Plate XVIII, fig.2) and, to a certain extent, POJ 2725 have given uniformly high germinations year after year, while certain typical *S. officinarum* varieties such as Vellai, Chittan, Striped Mauritius (Plate XVIII, fig. 1) and Gillman* have consistently yielded poor seed germinations. Mauritius 55 and 131 are, however, instances of *S. officinarum* type of canes which have given satisfactory germinations. *S. spontaneum* (both Coimbatore and Java forms) tops the list. Among the commercial varieties there is an improvement as we come to Co 205 and Co 285, apparently due to the *S. spontaneum* which they possess. Cos 213 and 290, on the other hand, give moderate germinations. A judicious combination of *S. officinarum* and *S. spontaneum* blood in Co 419 and Co 421 has resulted in these varieties giving seed of high germinating capacity.

For the large majority of cases in Table I, a variation will be noticed from year to year due, most probably, to the weather conditions—chiefly rainfall—prevailing at the flowering time. It is well known that such rains adversely affect seed setting.

---

* This is a bud sport obtained from Striped Mauritius.

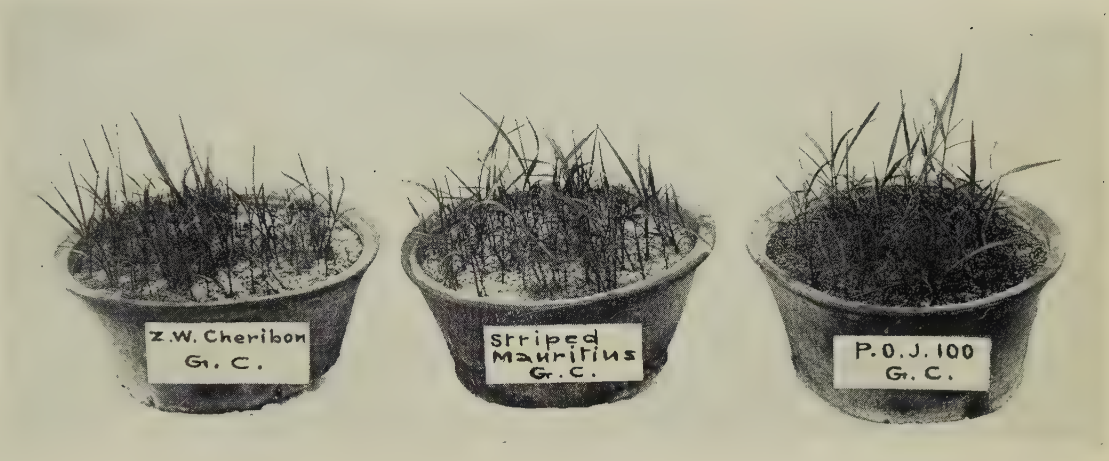

Z.W. Cheribon
G. C.
Striped Mauritius
G. C.
P.O.J. 100
G. C.

FIG. 1. Seed-pans showing poor germinations of seeds of certain sugarcane varieties

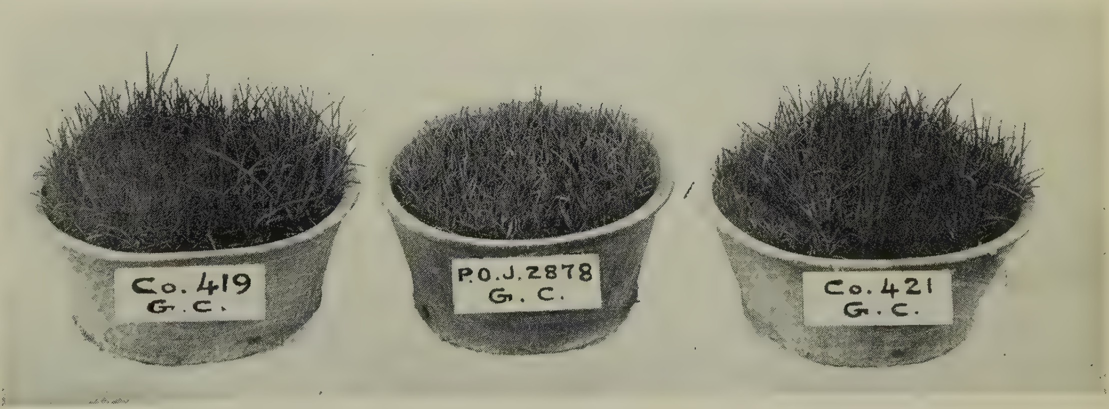

Co. 419
G. C.
P.O.J. 2878
G. C.
Co. 421
G. C.

FIG. 2. Seed-pans showing satisfactory germinations of seeds of certain sugarcane varieties

(c) *Influence of pollinating parent on seed-germination*

The differential effect of various pollinating parents on the same female variety will be seen from Table II. The pollen of over fifteen varieties was dusted on Vellai and though the pollen of Co 205 and Co 243 gives high percentage of germinations as tested on artificial culture media [Dutt and Ayyar, 1928 ; Dutt, 1929], the seed germinations of Vellai × Co 205 and Co 243 are poor as compared with D 74 and 247 B, whose pollen-germination percentages are low. Similarly, Co 285 which is well known for its high pollen germination, has given rise to only moderate seed germination in the cross Vellai × Co 285. Varieties with such high pollen germinations as *S. spontaneum* (Coimbatore), Glagah and Saretha have also been no exceptions. On the other hand, the thick seedling varieties B 3412 and D 131, whose pollen germinations are high, have yielded high germinations in the crosses Vellai × B 3412 and Vellai × D 131. From the above data there would appear to exist a certain amount of incompatibility between the species of *Saccharum*. This point, which is well worth investigation, will be made the subject of further studies.

The crosses made with Chittan, Karun, and Striped Mauritius as female parents are also similar to Vellai in that they give poor germinations even with the best male parents like Co 243 and Co 285. Further, Karun and Chittan have given poor germinations, also with the only thick cane male parent used on them, namely, 247 B. Based on experience, it may be said that though certain *S. officinarum* varieties like Vellai, Karun, Chittan, and Striped Mauritius may yield very good seedlings off and on, the care and labour involved in raising a large population is far too great. The inherent capacity of these varieties for seed germinations is low ; for instance, Vellai, even in the most favourable combination, hardly ever gives 200 germinations per seed-pan. On the other hand, varieties like POJ 2878 have, from the point of view of breeding of economic types, been found to be quite good. No dearth of seedlings is felt when such varieties are used as ovule parents and it is possible to repeat the majority of the desired crosses year after year as varieties like POJ 2878 seldom fail to flower. In the number of germinations even the lowest for POJ 2878 in any combination is over 200 per seed-pan, while in quite a number of crosses it exceeds 600.

The variety B 6308 was used for a few seasons as a female parent and in one or two on a fairly large scale. It was only in the cross B 6308 × Co 290 that satisfactory type of seedlings were obtained and even these after further tests had to be discarded. The preference of B 6308 for Co 290 lends support to the view that, as regards not only compatibility but also the securing of desirable type of seedlings, the problem is intimately connected with inter-varietal rather than inter-specific crosses, that is, the most suitable pollinating parents for each female variety can be ascertained only after experimentation.

IV. GERMINATION OF SEED FROM PEDICELLED AND SESSILE SPIKELETS

It was noticed, while examining some pans in which the seeds had just germinated, that most of the germinations were from sessile spikelets. As the pans in question related to a thick cane cross it was thought that the above characteristic might hold true for *S. officinarum* varieties in which the sessile spikelets usually open first and the converse might be the case for *S. spontaneum* and *S. barberi*, where the pedicelled spikelets are the first to open. To test this, some crosses and G. Cs. were taken, the seeds of pedicelled and sessile spikelets separated and sown in different pans. The result of germination counts are given in Table IV. It will be seen that more germinations were obtained from seeds of sessile spikelets in all cases including *S. spontaneum* G. C. It was further observed that the seedlings from the sessile spikelets were relatively more vigorous. Percentages of seed setting were determined in sessile and pedicelled spikelets. For this, 300 sessile and 300 pedicelled spikelets were examined in certain crosses. It will be seen from Table V that there were more seed settings in the sessile than in the pedicelled spikelets.

V. SIZE OF SEED IN CERTAIN SPECIES OF *Saccharum*

Observations were made on the length and thickness of seeds from the general collections (G. C.) of five representative varieties of three species of *Saccharum* and Co 205, an inter-specific hybrid (*S. officinarum* × *S. spontaneum*) (Table III). The measurements are the average of over one hundred readings. The diameter of the cane stalk is also given in each case, and it will be seen from the last column (Table III) that there is a high positive correlation between the thickness of the cane stalk and the length as also width of the seed.

VI. SUMMARY

1. The seed-germinations of over forty varieties were studied for five to seven seasons. Varieties like POJ 2725 gave uniformly high germinations, while *S. officinarum* varieties, such as Vellai, Chittan, etc., gave consistently low germinations. The *S. spontaneum* forms topped the list. A judicious combination of *S. officinarum* and *S. spontaneum* blood in Co 419 and Co 421 has resulted in these varieties, giving seed of high germinating capacity.

2. The attempt to improve germination by chemical means was not successful.

3. While a certain amount of influence of the pollinating parent was evident, the high or low germinations seem to depend more on the inherent capacity of the female parent.

4. The securing of desirable type of seedlings appears to be intimately connected with nter-varietal rather than inter-specific crosses.

5. Seeds of sessile spikelets gave more germinations than those of pedicelled ones in all the cases examined, including *S. spontaneum.*

6. There is a high positive correlation between the thickness of the cane and the length as also width of the seed.

REFERENCES

Barber, C. A. (1916). *Mem. Dept. Agric. Ind. (Bot. Ser.)* **8**, No. 3, 103-199

Dutt, N. L. (1929). *Agric. J. Ind.* **24**, 235-244

Dutt, N. L. and Ayyar, G. G. (1928). *Agric. J. Ind.* **23**, 190-202

Venkatraman, T. S. (1925). *Agric. J. Ind.* **20**, 173-186

TABLE

Seed-germinations in G.

Varieties	1928-29			1929-30			1930-31		
	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan
Vellai	600	20	30	190	10	19	420	25	17
K. Boothan	145	5	29	75	5	15	300	10	30
Karun	...	...	...	100	3	33	30	6	5
Chittan	...	...	...	50	3	17	160	15	11
Puri	...	...	...	30	3	10	...	...	...
Str. Mauritius	200	5	40	30	5	6	300	10	30
Green sport	280	5	56	75	3	25	1,500	7	214
Gillman	150	5	30	42	5	9	1,600	10	160
S. spontaneum (Coimbatore)	...	...	...	...	...	...	...	...	...
Glagah	...	...	...	...	...	...	...	...	...
B 3412	2,000	12	167	450	5	95	2,600	7	371
B 6308	425	11	39	200	5	40	2,200	12	183
CAC 87	...	...	...	...	...	...	...	...	...
D 74	700	10	70	200	6	34	500	10	50
D 131	6,160	26	237	1,500	3	500	1,200	5	240
HM 539	...	...	...	300	3	100	...	...	...
Maur 55	...	...	...	...	...	...	1,500	2	750
,, 131	1,866	5	373	600	5	120	3,700	12	308
,, 1237	20	3	7	...	...	...	...	...	...
POJ 100	200	5	40	55	5	11	110	5	22
,, 1410	75	5	15	...	...	...	3,000	10	300
,, 2364	...	...	...	1,400	9	156	4,000	8	500
,, 2696	700	2	350	...	...	...	2,500	4	625
,, 2725	150	1	150	800	10	80	5,000	10	500
,, 2727	1,145	5	229	40	7	6	3,000	16	189
,, 2878	...	...	...	9,000	15	600	4,200	9	467
EK 28	250	10	25	400	5	80	900	10	90
SW 111	150	5	30	2,300	6	383	3,500	5	700
247 B	200	10	20	140	9	16	1,500	10	150
Q 813	350	7	50	240	18	13	1,500	7	215
Co 205	...	...	...	...	...	...	...	...	...
,, 213	75	3	25	15	2	8	1,700	5	340
,, 243	...	...	...	700	1	700	1,200	3	400
,, 281	...	...	...	...	...	...	...	...	...
,, 285	...	...	...	720	1	720	1,200	1	1,200
,, 290	...	...	...	700	5	140	600	10	60
,, 360	...	...	...	...	...	...	350	9	30
,, 361	...	...	...	...	...	...	4,500	10	450
,, 363	...	...	...	...	...	...	...	...	...
,, 400	...	...	...	...	...	...	...	...	...
,, 403	...	...	...	...	...	...	...	...	...
,, 405	...	...	...	...	...	...	...	...	...
,, 406	...	...	...	...	...	...	...	...	...
,, 408	...	...	...	...	...	...	...	...	...
,, 413	...	...	...	...	...	...	...	...	...
,, 415	...	...	...	...	...	...	...	...	...
,, 419	...	...	...	...	...	...	...	...	...
,, 421	...	...	...	...	...	...	...	...	...

Cs. of different varieties

1931-32			1932-33			1933-34			1934-35			1935-36		
Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan
12	3	4	75	25	3	150	5	30	72	3	24	...	...	...
20	5	4	12	5	2	240	5	48	479	3	160	90	4	23
...	...	...	4	5	1	...	...	...	22	3	7	...	...	...
27	4	7	25	5	5	...	...	...	19	5	4	...	...	...
...	...	...	6	3	2	8	2	4	...	...	...	...	...	...
200	4	50	36	6	6	230	2	115	50	5	10	40	3	13
85	5	17	35	5	7	...	...	...	...	...	...	...	...	...
70	5	14	35	5	7	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	2,102	3	704	...	...	...
...	...	...	...	...	...	...	...	...	1,972	3	657	...	...	...
...	...	...	79	6	13	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	60	12	5	...	...	...	...	...	...
260	10	26	100	3	33	360	3	120	...	...	...	...	...	...
400	5	80	110	8	14	...	...	...	70	5	14	300	7	43
...	...	...	100	2	50	...	...	...	...	...	...	...	...	...
1	1	1	...	...	...	...	...	...	...	...	...	...	...	...
1,700	4	425	...	...	...	240	4	60	200	3	67	...	...	...
1,200	6	200	900	6	150	60	2	30	...	...	...	...	...	...
32	2	16	...	...	...	91	8	11	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1,250	5	250	130	5	26	700	5	140	...	...	...	...	...	...
631	3	210	...	...	...	670	4	168	300	5	60	...	...	...
600	3	200	...	...	...	360	3	120	...	...	...	...	...	...
1,500	4	375	379	6	63	1,300	4	325	320	5	64	1,200	3	400
180	3	60	107	6	18	650	6	108	...	...	...	...	...	...
3,000	8	375	704	6	117	3,000	6	500	1,700	5	340	1,900	3	633
40	8	5	130	5	26	35	3	12	10	5	2	36	7	5
...	...	...	...	...	...	2,000	5	400	...	...	...	...	...	...
250	5	50	14	2	7	120	5	24	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1,800	3	600	...	...	...	...	...	...	...	...	...	...	...	...
650	3	216	245	6	41	230	3	77	...	...	...	...	...	...
1,100	3	367	...	...	...	...	...	...	...	...	...	...	...	...
2,000	4	500	870	6	145	2,200	3	733	...	...	...	...	...	...
3,465	3	1,155	521	3	174	...	...	...	...	...	...	...	...	...
47	3	16	50	4	13	330	4	83	...	...	...	...	...	...
147	9	16	700	10	70	2,530	5	506	...	...	...	...	...	...
3,000	6	500	...	...	...	2,060	3	687	1,100	5	220	...	...	...
236	10	24	...	...	...	305	4	76	...	...	...	250	5	50
46	8	6	1,200	15	80	1,840	12	153	...	...	...	...	...	...
...	...	...	400	5	80	900	8	113	...	...	...	...	...	...
...	...	...	...	...	...	1,200	4	300	...	...	...	...	...	...
...	...	...	...	...	...	1,800	4	450	...	...	...	...	...	...
...	...	...	300	5	60	1,600	5	320	500	5	100	...	...	...
...	...	...	...	...	...	900	6	150	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	1,660	5	332	...	...	...
...	...	...	...	...	...	5,000	8	625	1,660	5	320	2,600	5	520
	...	...	...	...	...	...	...	...	1,850	5	370	6,200	8	775

TABLE II

Influence of pollinating parent on seed-germination

Cross	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36
Vellai × EK 28	...	...	...	...	240	...	...
× Co 243	112	17	...	29	13	113	...
× POJ 2878	186	25	60	19	...	53	...
× 247 B	234	...	...	...	...	...	...
× B 3412	215	...	133	247	...	168	...
× Co 281	8	...	...	...	...	...	...
× D 74	72	125	...	...	...	...	...
× Co 290	4	...	...	...	...	...	...
× POJ 2727	...	19	...	...	...	...	...
× Co 285	...	8	...	...	...	88	...
× POJ 1410	...	...	10	...	...	...	...
× Glagah	...	...	...	12	...	56	...
× Co 205	...	...	...	15	19	...	...
× K. Boothan	...	...	...	11	...	...	5
× *S. spontaneum* (Coimbatore).	...	...	...	...	...	40	7
× D 131	...	...	...	...	...	199	...
× Saretha	...	...	...	...	...	56	14
Maur 1237 × Co 285	30	...	...	...	...	...	...
× B 3412	30	...	...	...	...	...	...
× Co 243	121	...	...	...	...	175	...
× D 74	107	...	...	...	...	...	...
× Co 281	20	...	...	...	...	...	...
× Q 813	8	...	...	...	...	...	...
× Co 290	50	...	...	...	...	...	...
× Fiji B	22	...	...	...	...	...	...
× Co 213	...	...	...	150	...	...	...
B 6308 × Co 281	188	...	...	85	...	...	...
× Co 290	40	344	...	...	...	61	...
× D 74	142	435	...	...	...	...	...
× Fiji B	150	...	...	...	...	...	...
× Q 813	200	...	...	...	...	...	...
× EK 28	...	190	...	...	...	...	...
× Co 214	...	50	...	...	...	...	...
× Co 243	...	360	...	...	...	...	...
× Co 360	...	...	100	...	...	...	...
× POJ 1410	...	...	90	...	...	...	...
× CAC 87	...	...	36	...	...	...	...
× Co 419	...	...	...	...	110	...	...

TABLE II—*contd.*

Influence of pollinating parent on seed-germination—contd.

Cross	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36
POJ 2878×B 3412	233	...	...	...	...	...	...
×Co 243	375	755	...	...	...	...	...
×Co 285	643	...	...	...	...	...	...
×Co 361	...	666	...	...	...	...	...
×POJ 2727	...	666	...	...	...	...	...
×EK 28	...	950	...	...	...	...	...
×D 74	...	375	...	...	...	...	...
×Co 290	...	350	...	367	302	...	...
×Co 214	...	633	...	...	...	...	...
×Co 364	...	...	725	...	...	...	...
×EK 2	...	...	...	700	...	...	...
×Co 281	...	...	...	...	...	550	...
×P 1587	...	...	...	...	...	520	...
×Co 213	...	...	...	...	...	...	285
×Co 331	...	...	...	...	...	...	704
×Co 508	...	...	...	...	...	...	611
Co 290×247 B	60	...	...	...	...	...	133
×Q 813	66	...	...	...	...	...	...
×SW 111	50	...	...	...	...	...	...
×Fiji B	39	...	...	...	...	...	...
×POJ 2878	...	72	...	...	...	...	160
Kassoer ×D 131	50	...	...	...	...	...	...
×B 3412	50	...	...	...	...	...	...
×Co 290	650	...	...	...	...	...	...
×Fiji B	100	...	...	...	...	...	...
×BH 10 (12)	400	...	...	...	...	...	...
Chittan×Co 243	140	...	...	...	...	...	...
×247 B	32	...	...	...	...	...	...
Karun×Co 243	55	...	...	...	...	66	...
×247 B	50	...	...	...	...	...	...
×Co 244	...	...	...	...	...	33	...
×Co 312	...	...	...	...	...	42	...
×POJ 2878	...	...	...	...	...	53	...
×CAC 87	...	...	...	...	...	30	...
×P 1629	...	...	...	...	...	109	...
Striped Mauritius×Co 290	27	...	...	...	...	...	...
×Co 285	...	...	...	...	...	36	...
×Co 360	...	...	...	...	...	11	...

TABLE III

Seed measurements

Variety from which the general collection was taken	Diameter of the cane stalk in mm.	Length of the seed in μ	Width of the seed in μ	Coefficient of correlation
S. spontaneum (Coimbatore)	6·64	1192·95	461·45	Between diameter of cane and length of seed.
S. spontaneum (Java) Glagah	10·53	1416·25	555·50	
Saretha (*S. barberi*)	17·18	1301·02	569·25	$r=+0\cdot89\pm0\cdot085$.
Co 205 (Vellai × *S. spont.*)	17·87	1574·37	523·05	Between diameter of cane and width of seed.
K. Boothan (*S. officinarum*)	26·60	1561·17	582·17	
Vellai (*S. officinarum*)	34·18	1787·50	607·75	$r=+0\cdot82\pm0\cdot134$.

TABLE IV

Percentage of germinations of seeds from sessile and pedicelled spikelets

Cross	Germinations out of 500 sessile spikelets	Per cent	Germinations out of 500 pedicelled spikelets	Per cent
S. spontaneum G. C.	29	5·8	20	4·2
Co 205 G. C.	175	35·0	151	30·2
Co 421 × Co 285	288	57·6	220	44·0
Co 419 × Co 285	189	37·8	123	24·6

TABLE V

Seed-setting in sessile and pedicelled spikelets

Cross	Seed-setting out of 300 sessile spikelets	Per cent	Seed-setting out of 300 pedicelled spikelets	Per cent
Vellai × EK 28 . .	95	31·66	48	16·00
Co 400 × EK 28 . .	133	44·30	75	25·00
Co 243 × Co 205 . .	69	23·00	32	10·60
Vellai × Co 205 . .	9	3·00	2	0·60
Co 400 × Co 205 . .	108	36·00	54	18·00
Co 243 × EK 28 . .	34	11·30	21	7·00

TABLE VI

Germinations of seed variously treated before sowing

——	Ortho-phosphoric acid	Water	H_2SO_4	Soil-fluff mixture	Control	Remarks
POJ 2725 . .	1085	1035	28	1241	1500	Germination counts are totals of three seed-pans in each treatment.
POJ 2878 . .	313	390	10	485	1400	
SW 111 . .	1326	1653	305	1793	2100	
Co 243 . .	610	885	13	957	1200	
K. Boothan . .	59	70	2	132	90	

A NOTE ON THE USE OF SUB-ACETATE OF LEAD IN THE CLARIFICATION OF SUGARCANE JUICE FOR THE ESTIMATION OF REDUCING SUGARS BY THE POTASSIUM FERRICYANIDE METHOD

BY

K. L. KHANNA

AND

S. C. SEN

Sugarcane Research Scheme, Bihar

(Received for publication on 22nd February 1938)

THE Fehling's method for the estimation of glucose in cane juice is now widely accepted, although the necessary use of sodium phosphate filtrate makes it laborious and time-consuming, so that, where large rounds of analyses have to be completed within the course of each day, as is the case in sugarcane research laboratories, an accurate, yet quick method, in its place is a desideratum.

Encouraging results were recently obtained [Sen, 1937] when an alkaline potassium ferricyanide solution—a slight modification of Cole's method [1933]—was used in place of Fehling's solution against a sodium phosphate filtrate in defining more accurately the end-point of the titration, but results with the lead sub-acetate filtrate directly were erratic due mainly to the formation of a white precipitate of complex salts of ferro and ferricyanide of lead. Attempt was, therefore, made to see if, by regulating the quantity of lead sub-acetate used for clarifying the juice, the formation of the white precipitate could be avoided, as the direct use of lead sub-acetate filtrate would considerably cut short the time of analysis, for both the estimations of sucrose and glucose could be done from the same filtrate.

A number of experiments were, therefore, conducted where different doses of lead sub-acetate ranging from 1·0 gram to 10·0 grams for each 150 c.c. of original cane juice were tried for clarification and the filtrates were directly titrated against one per cent alkaline ferricyanide solution. The results thus obtained were compared with the usual Fehling's and potassium ferricyanide results (Table I).

TABLE I

Comparative results of glucose estimation

Standard solutions	Vol. of lead sub-acetate filtrate required for titration when 2·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol. of lead sub-acetate filtrate required for titration when 3·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol. of lead sub-acetate filtrate required for titration when 4·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol· of lead sub-acetate filtrate required for titration when 5·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol. of lead sub-acetate filtrate required for titration when 6·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol. of lead sub-acetate filtrate required for titration when 8·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol. of lead sub-acetate filtrate required for titration when 10·0 grms. of lead sub-acetate was used for clarification of 150 c.c. of cane juice	Vol. of sodium phosphate filtrate required for titration
20·0 c.c. 1 per cent ferricyanide solution.	9·33±0·05	9·33±0·05	9·25±0·05	....	9·83±0·02	9·70±0·04	10·40±0·00	9·33±0·02
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	9·35±0·00
20·0 c.c. 1 per cent ferricyanide solution.	2·40±0·00	2·42±0·02	2·45±0·00	2·50±0·03	3·08±0·02	3·16±0·02	3·38±0·05	2·40±0·00
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	2·40±0·00
20·0 c.c. 1 per cent ferricyanide solution.	4·22±0·01	4·20±0·00	4·28±0·02	4·33±0·02	4·40±0·03	4·62±0·04	4·60±0·04	4·20±0·00
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	4·20±0·00
0·0 c.c. 1 per cent ferricyanide solution.	4·06±0·01	4·05±0·01	4·08±0·04	4·22±0·02	...	...	...	4·10±0·00
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	4·07±0·02
20·0 c.c. 1 per cent ferricyanide solution.	8·23±0·03	8·36±0·05	...	8·10±0·08	...	...	...	8·22±0·02
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	8·23±0·01
20·0 c.c. 1 per cent ferricyanide solution.	2·49±0·01	2·50±0·01	2·56±0·05	2·73±0·02	...	...	...	2·46±0·01
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	2·47±0·01
20·0 c.c. 1 per cent ferricyanide solution.	5·24±0·01	5·27±0·02	5·34±0·07	5·35±0·08	...	...	...	5·26±0·01
4·0 c.c. Fehling's . . .	...	...	...	...	...	...	...	5·27±0·02

From the data given in Table I above it is evident that the lead sub-acetate filtrate can be directly employed for the estimation of glucose, provided only 2-3 grams of lead sub-acetate are used for clarifying each 150 c.c. of the original cane juice. With one gram of lead sub-acetate the clarification is barely complete, while more than 3 grams result in lower readings for glucose being obtained.

The exact experimental procedure consists in taking 20 c.c. of one per cent potassium ferricyanide solution in a 150 c.c. conical flask and adding to it 5 c.c. of 5 per cent caustic potash and a drop of one per cent methylene-blue. Into this cold solution is run from the burette, roughly half the total quantity of sugar solution (*i.e.* lead sub-acetate filtrate) required for complete titration and the flask is heated to boiling on wire gauze over a flame. After each boiling the flame is lowered to permit of more sugar solution being added from the burette and this process is repeated till the entire fluid in the flask is decolourised when reading for the quantity of sugar solution used is taken. At the approach of end-point the fluid usually shows an amethyst violet colour which is an indication for extreme caution as just one or two further drops of the solution are required for the final point. The exactness of the titration can be tested by lightly shaking the flask within thirty seconds of the end-point when the methylene-blue colour reappears. Where excess of sugar has been used, longer time is invariably required. The whole titration takes about two to three minutes. The method has been tested on a large number of varieties over the past two seasons and consistent results (Table II) have been obtained.

TABLE II

Comparative results of glucose estimation with lead sub-acetate and sodium phosphate filtrates

1 Serial No. of test	2 Vol. of lead sub-acetate filtrate required for titration (when 2·0 grm. lead sub-acetate used for clarification) against 20 c.c. of one per cent $K_3Fe(CN)_6$ solution	3 Vol. of sodium phosphate filtrate required for titration against 4·0 c.c. of Fehling's solution
1	2·45	2·45
2	9·30	9·25
3	4·25	4·30
4	4·20	4·20
5	9·30	9·35
6	4·10	4·20

TABLE II—*contd.*

1 Serial No. of test	2 Vol. of lead sub-acetate filtrate required for titration (when 2·0 grm. lead sub-acetate used for clarification) against 20 c.c. of one per cent $K_3 Fe (CN)_6$ solution	3 Vol. of sodium phosphate filtrate required for titration against 4·0 c.c. of Fehling's solution
7	5·25	5·25
8	2·50	2·45
9	8·20	8·20
10	4·05	4·05
11	2·45	2·40
12	2·10	2·05
13	4·90	4·85
14	4·15	4·10
15	3·25	3·30
16	3·45	3·55
17	4·95	4·95
18	7·85	7·80
19	5·25	5·30
20	5·75	5·75
21	10·15	10·15
22	2·30	2·30
23	4·10	4·20
24	1·55	1·50
25	2·20	2·20
26	2·45	2·40
27	8·10	8·15
28	8·30	8·30

TABLE II—*contd.*

1 Serial No. of test	2 Vol. of lead sub-acetate filtrate required for titration (when 2·0 grm. lead sub-acetate used for clarification) against 20 c.c. of one per cent $K_3\,Fe\,(CN)_6$ solution	3 Vol. of sodium phosphate filtrate required for titration against 4·0 c.c. of Fehling's solution
29	5·70	5·65
30	3·25	3·30
31	5·50	5·50
32	4·85	4·80
33	4·40	4·45
34	3·70	3·70
35	10·25	10·30
36	11·15	11·15
37	9·30	9·35
38	7·25	7·20
39	10·75	10·70
40	8·70	8·80
41	3·50	3·60
42	4·25	4·25
43	6·75	6·80
44	6·30	6·40
45	7·10	7·30
46	1·10	1·10
47	8·20	8·25
48	7·85	7·85
49	4·70	4·75
50	3·85	3·90

TABLE II—*concld.*

1 Serial No. of test	2 Vol. of lead sub-acetate filtrate required for titration (when 2·0 grm. lead sub-acetate used for clarification) against 20 c.c. of one per cent K_3 Fe $(CN)_6$ solution	3 Vol. of sodium phosphate filtrate required for titration against 4·0 c.c. of Fehling's solution
51	2·00	2·00
52	3·70	3·75
53	2·80	2·90
54	2·10	2·10
55	1·70	1·80
56	3·90	3·95
57	3·50	3·50
58	3·90	3·85
59	3·00	3·05
60	3·70	3·70

SUMMARY

1. A method for the quick estimation of glucose in cane juice is described and it consists in the direct use of lead sub-acetate filtrate for titration of glucose with one per cent alkaline potassium ferricyanide solution.

2. The method qualifies that only 2 to 3 grams of lead sub-acetate should be used for clarifying each 150 c.c. of the original cane juice, as higher quantities have been found to give lower readings for glucose.

3. A close correspondence between the results obtained from the direct use of lead sub-acetate filtrate against potassium ferricyanide solution; and those with the usual sodium phosphate filtrate against Fehling's and ferricyanide solutions, has been demonstrated.

REFERENCES

Cole, S. W. (1933). *Biochem. J.* **27**, 723-736

Sen, S. C. (1937). *J. Ind. Chem. Soc.* **13**, 2

DENITRIFICATION IN THE PRESENCE OF SUGARS

BY

S. V. DESAI, D.Sc., Ph.D., D.I.C.

Agricultural Bacteriologist, Punjab Agricultural College, Lyallpur

AND

FAZAL-UD-DIN, B.Sc.

Bacteriological Assistant

(Received for publication on 15th February 1938)

(With one text-figure)

It has been shown [Fazal-ud-Din, 1936] that photo-reduction of nitrates is greater in presence of carbohydrates than in their absence. This observation is interesting in so far as it seems to have some bearing on the denitrification of mineral nitrogen in manured soils and it was therefore felt necessary to find out how the reaction proceeded, what part carbohydrates played in the process of denitrification and how they themselves were changed. The study of these reactions is likely to throw some light on the changes that take place in the soil on application of molasses and is likely to be helpful in determining the circumstances for successful use of molasses as a manure.

METHODS OF ANALYSIS

(1) Nitrous+nitric nitrogen : By Lunge's Nitrometer.

(2) Nitrous nitrogen :

(*a*) By Griess Ilosvay's method.

(*b*) By Warburg's Iodimetric method.

(3) Nitric nitrogen : By difference.

(4) Ammoniacal nitrogen : By distillation of ammonia in $N/70$ sulphuric acid in a micro-distillation apparatus.

(5) Carbon : By oxidation with hot chromic acid in presence of sulphuric acid and absorbing the carbon dioxide in a standard baryta solution after washing.

(6) Glucose : By Fehling's solution.

(7) Hydrogen-ion concentration : By Hellige Comparator.

(8) Titrable acidity : By titration with $N/70$ caustic soda using phenolphthalein as an indicator.

One hundred c.c. of potassium nitrate solution, containing one mg. of nitrogen per c.c. were transferred to 300-c.c. conical flasks. These were divided into four sets of three flasks each. Different amounts of glucose were added to each set. The flasks were plugged with cotton wool, sterilized and exposed to the sun. Nitrous nitrogen was estimated after nine hours' exposure. It was found that the reduction of nitrate was not affected by increase in concentration of glucose. The experimental results are given in Table I.

TABLE I

Reduction in presence of different amounts of glucose

Serial No.	Glucose (Grms. per 100 c.c.)	Nitrous nitrogen (Mgs. per 100 c.c.)
1	0·5	0·136
2		0·155
3		0·143
4	1·0	0·143
5		0·142
6		0·143
7	2·0	0·143
8		0·143
9		0·149
10	4·0	0·136
11		0·136
12		0·143

In order to study the kinetics of the reaction an experiment was set up as follows :—

Five litres of potassium nitrate solution containing about one milligram of nitrogen per c.c. were prepared. The solution was divided into two equal portions. To one portion, 25 grms. of glucose were added, while the other was left as such. These solutions were distributed in 300-c.c. conical flasks in 100-c.c. portions. The flasks were plugged with cotton wool. Pieces of paper were tied over the plugs to guard against contamination during the exposure. These were then sterilized in flowing steam for half an hour on three consecutive days, and exposed to the sun. Of these, six flasks—three with glucose and three without glucose—were wrapped in black paper. Nitrous nitrogen was estimated at different intervals. The flasks used once were discarded. The results given in Table II showed that in the earlier stages nitrous nitrogen was present in greater quantities in flasks containing glucose and went on increasing during the first nine hours, and then it began to decrease ; while in the flasks without glucose, nitrous nitrogen continued to increase at a steady rate, so that at the end of eighty-four hours, the amount of nitrous nitrogen in the flasks without glucose was more than in those containing glucose.

TABLE II

Nitrous nitrogen in KNO_3 solution at different intervals

Treatment No.	Mg. of nitrous nitrogen per 100 c.c.					
	3 hours	6 hours	9 hours	36 hours	84 hours	180 hours
1. Without glucose . .	0·023 0·024 0·025	0·034 0·041 0·036	0·055 0·054 0·068	0·117 0·110 0·104	0·123 0·136 0·104	0·155 0·181 0·155
2. With glucose . . .	0·071 0·055 0·060	0·113 0·104 0·142	0·175 0·162 0·194	0·123 0·130 0·123	0·065 0·065 0·065	0·058 0·052 0·058

The hydrogen-ion concentrations of solutions were also determined. The results (Table III) showed that in the absence of glucose, the *p*H value remained practically unchanged while in the presence of glucose, it decreased rapidly during the first nine hours and later at a much slower rate. The lowering of *p*H in the presence of glucose is due to the formation of acids by photo-oxidation. The low *p*H value of the solution is known to exercise a retarding effect on the process of reduction of nitrates, and therefore it may be inferred that had the reaction remained neutral or alkaline during the exposure, the amount of nitrate reduced would have been greater than that actually found in the experiment. Another set of flasks was analysed after eight days for ammoniacal, nitrous and nitric nitrogen. The results (Table IV) showed that in the exposed flasks the amount of both nitrous and nitric nitrogen was less in the presence of glucose than in its absence. Ammoniacal nitrogen was present only in traces.

TABLE III

pH of KNO_3 solutions at different intervals

Treatment	Hours			
	9	36	84	180
Without glucose .	7·0 7·0 7·0	7·0 7·1 7·1	7·1 7·1 7·1	7·1 7·1 7·1
With glucose . .	3·8 3·8 3·8	3·6 3·6 3·6	3·1 3·1 3·1	3·2 3·2 3·1

TABLE IV

Distribution of nitrogen in KNO_3 solution after eight days

Mgs. of nitrogen per 100 c.c. solution

Treatment	Exposed			Unexposed		
	Nitric N	Nitrous N	Ammoniacal N	Nitric N	Nitrous N	Ammoniacal N
Without glucose	102	0·29	Trace	101	Trace	*Nil*
	100	0·25	,,	102	,,	,,
	102	0·25	,,	101	,,	,,
With glucose .	97	0·03	,,	101	,,	,,
	98	0·03	,,	101	,,	,,
	96	0·03	,,	99	,,	,,

It was interesting to note that nitrogen was lost from the exposed flasks in presence of glucose. It seemed that nitrite, which was being formed continually by the reduction of nitrate, was being decomposed into gaseous nitrogen, and this accounted for smaller amounts of nitrite in the presence of glucose than in its absence. This also showed that the decomposition of nitrite was proceeding at a greater rate than its production from nitrate. It was therefore decided to study the decomposition of nitrite in the presence of carbohydrates and sunlight, and also to see if the nature of the carbohydrate used had any effect on the denitrification.

Sodium nitrite solutions with and without sugars were prepared as before, put in flasks, sterilized and divided into two similar sets. The flasks in one set were wrapped in black paper and these along with others were exposed to the sun for three weeks and analysed. The results (Table V) showed that large amount of nitrogen was lost in the presence of sugars.

TABLE V

Denitrification of sodium nitrite solution in presence of sugars
(Mgs. of nitrogen per 100 c.c.)

Treatment	Unexposed				Exposed				Average loss
	Nitric N	Nitrous N	Ammoniacal N	Total	Nitric N	Nitrous N	Ammoniacal N	Total	
Without sugar	7	143	0·03	150	12	137	0·08	149	
	8	142	0·01	150	14	136	0·00	150	0·3
	8	141	0·01	149	12	137	0·24	149	
Glucose	7	138	0·10	145	37	39	10·40	86	
	6	137	0·10	143	42	39	11·36	92	55
	5	140	0·10	145	40	41	9·68	91	
Sucrose	4	138	0·10	142	42	40	9·92	92	
	5	140	0·06	145	39	41	9·44	89	54
	7	138	0·04	145	38	40	9·84	88	
Maltose	5	140	0·06	150	55	45	8·88	109	
	6	140	0·02	146	48	47	6·56	102	42
	8	138	0·06	146	44	52	9·12	105	
Fructose	8	128	0·10	136	47	27	8·56	83	
	6	132	0·10	138	42	27	8·56	78	54
	8	128	0·10	136	49	28	9·20	86	

The reduction of nitrite to ammonia was also appreciable. It is probable that the simultaneous existence of nitrite and ammonium ions in the presence of sunlight leads to the loss of nitrogen by simple decomposition :

$$NH^{\cdot}_4+NO'_2=2H_2O+N_2$$

It is also possible that the direct reduction of nitrite into gaseous nitrogen is taking place side by side. A small amount of nitrogen may as well be lost by decomposition of nitrous acid into oxides of nitrogen when the solution becomes acidic.

A part of the nitrous nitrogen was changed into nitric nitrogen which shows that the sugars or their oxidation products act as oxidising catalysts. Similar action of the sugars was noticed by Desai and Fazal-ud-Din [1936], but the action was very feeble.

Disaccharides like sucrose and maltose were as effective as monosaccharides and therefore it is indicated that the nature of carbohydrate does not affect the reaction materially.

All the sugars reacted with nitrite and formed ammonia even in the absence of light. The loss of nitrogen which followed was very small as compared to that which occurred in presence of sunlight.

The possibility of nitrogen entering into combination with certain organic radicals and thus escaping estimation in the usual determinations carried out was considered and an experiment to test the solution for organic nitrogen was therefore conducted.

Thirty c.c. of the solution showing denitrification were decomposed in a nitrometer with sulphuric acid in presence of mercury. The solution freed from nitrous and nitric nitrogen was digested with sulphuric acid and nitrogen was estimated. It was found that nitrogen content of the solution was equal to the ammoniacal nitrogen content of the original solution. This showed that organic compounds containing nitrogen were not formed during the reaction.

In order to obtain a direct evidence of evolution of nitrogen an experiment was conducted to see if nitrogen gas was actually produced in the reaction.

Three glass tubes (Fig. 1) of about one inch diameter were completely filled with a solution containing 5 per cent dextrose and 5 per cent sodium nitrite. The solution was partially displaced by oxygen and the tubes were hermetically sealed, sterilized and exposed to the sun. The enclosed gases were analysed after twelve days. The results given in Table VI showed that nitrogen gas was evolved from sodium nitrite.

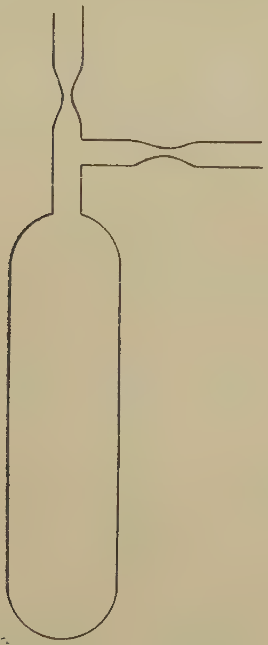


FIG. 1. Type of glass tube used

TABLE VI

Evolution of nitrogen during the reduction of sodium nitrite
(Volume in c.c.)

Serial No.	Total gas	Nitrogen
1	36·6	31·4
2	29·3	23·0
3	27·6	26·7

An experiment was also conducted to see if the oxygen of the air was essential for denitrification of sodium nitrite. A glass tube (15×3 cm.) closed at one end was sealed to another glass tube (10×0·8 cm.). Six glass tubes of equal size were prepared. Forty c.c. of sodium nitrite solution containing one mg. nitrogen and ten mgs. glucose per c.c. were put into each of these tubes. Three tubes were plugged with cotton wool and the other three were exhausted and hermetically sealed. All the six tubes were sterilized and exposed to the sun in a slanting position and the contents were analysed after an exposure of twelve days. The results (Table VII) show that oxygen is not essential for denitrification.

TABLE VII

Denitrification in the presence and absence of air

Treatment	Mgs. per 100 c.c. solution					
	Nitric N	Nitrous N	Ammoniacal N	Total	Loss of nitrogen	Glucose
Plugged	11	25	11	47	53	532
Vacuum	6	25	14	44	56	595

The oxidation of sugar was slightly less in vacuum than in presence of air. The solutions in vacuum were found to be alkaline while the others were acidic to litmus.

In order to find out what changes took place in glucose during the process of denitrification, the following sets of flasks were prepared as before :—

1. Sodium nitrite.
2. Sodium nitrite + glucose.
3. Glucose.

After an exposure of four weeks the contents of the flasks were analysed for the following :—

1. Nitric nitrogen.
2. Nitrous nitrogen.
3. Ammoniacal nitrogen.
4. Glucose.
5. Total carbon.
6. Titrable acidity.
7. Hydrogen-ion concentration.

The results regarding nitrogen transformations confirmed those previously obtained. Both reduction and oxidation of nitrous nitrogen took place and the loss of nitrogen was found to be considerable (Table VIII).

TABLE VIII

Denitrification of $NaNO_2$ *solution*

(After 4 weeks)

Serial No.	Treatment	Mgs. of nitrogen per 100 c.c.				
		Ammoniacal	Nitrous	Nitric	Total	Nitrogen lost
1	Nitrite solution	0·2	93·2	5·6	99·0	..
2		0·1	89·6	6·0	95·7	..
3		0·1	89·6	5·4	95·1	..
4	Nitrite solution + glucose	5·5	12·3	11·1	28·9	..
5		5·2	11·8	17·0	34·0	64·8
6		5·1	11·8	15·7	32·6	..

The results of glucose estimations (Table IX) show that—

1. The oxidation of glucose is greater in the presence of sodium nitrite than in its absence. This may be due to the fact that sodium ions combine with glucose to form compounds which are known to be highly reactive, and thus accelerate the decomposition of the glucose molecule.

2. Twenty-four per cent of the glucose was completely oxidised to carbon dioxide and water and nineteen per cent was present in the form of intermediate products.

TABLE IX

Oxidation of glucose

(After 4 weeks)

Serial No.	Treatment	Mg. per 100 c.c. solution			
		Total carbon (calculated as glucose)	Glucose	Carbon other than glucose (calculated as glucose)	Glucose lost as CO_2 & H_2O
1	Nitrite solution + glucose	770	570	200	230
2		750	565	185	250
3		760	585	175	240
4	Glucose	944	975	..	..
5		935	955	..	..
6		961	965	..	..

The resulting solutions were tested for different acids qualitatively. On distilling an acidulated portion of the reaction mixture in steam, the distillate obtained was almost neutral and tests for volatile organic acids were negative.

The solution was tested directly for organic acids by treatment with neutral silver nitrate and with calcium hydroxide. A slight precipitate was obtained in either case, which showed that only small amounts of organic acids were formed under the conditions of the experiment. However, when the tests were repeated during the summer months, the precipitate was more pronounced.

The exposed solution generally had a faint smell resembling that of formaldehyde which may be due to the traces of formic acid formed from glucose before complete oxidation of the sugar molecule into carbon dioxide and water.

The titrable acidity was the greatest in the glucose solution containing nitrite (Table X).

TABLE X

Showing the reaction of the solution

(After 4 weeks)

Serial No.	Sample	Reaction	
		*p*H	*N*/70 soda required to neutralize 100 c.c. solution
1	Sodium nitrite solution	7·3	*Nil*
2		7·3	,,
3		7·3	,,
4	Sodium nitrite solution+glucose .	5·4	15·0
5		5·4	15·0
6		5·4	15·0
7	Glucose solution	4·4	1·5
8		4·1	1·5
9		4·2	1·5

The formation of organic acids by the oxidation of sugars is well known and further evidence in support of this is supplied by the above reactions. Titrable acidity rose to 15 c.c. of *N*/70 acid. The amount of acids formed was small as only a slight precipitate was obtained on addition of silver nitrate or calcium hydroxide solutions.

As a large amount of nitrogen is lost in gaseous form from sodium nitrite, an equivalent amount of sodium ions must be set free, and these would tend to make the solution alkaline. Corresponding to a loss of 64·8 mgs. of nitrogen from sodium nitrite, 46 c.c. of $N/10$ soda should have been produced. The solution, however, was found to be acidic. The organic acids being present only in a small amount, the large amount of sodium ions liberated must have combined with glucose. This, however, needs further investigation as the reaction took place in a slightly acidic solution, while the combination of sodium with glucose is known to take place in an alkaline medium.

CONCLUSIONS

1. The reduction of potassium nitrate in solution is accelerated by the addition of glucose. Nitrogen may even be lost as gas.
2. The reduction of nitrates is not affected by the concentration of glucose.
3. Sodium nitrite is readily denitrified in presence of sugars.
4. Denitrification is independent of the nature of the carbohydrates used.
5. Reduction of nitrite to ammonia also takes place.
6. Oxygen of the air is not essential for bringing about denitrification.
7. The oxidation of glucose to carbon dioxide, water, acids and other non-saccharine substances is greater in the presence of sodium nitrite than in its absence.

REFERENCES

Desai, S. V. and Fazal-ud-Din (1936). *Ind. J. Agric. Sci.* **6**, 985

Fazal-ud-Din (1936). *Ind. J. Agric. Soi.* **6**, 844

STUDIES ON QUALITY IN RICE

I. EFFECT OF MILLING ON THE CHEMICAL COMPOSITION AND COMMERCIAL QUALITIES OF RAW AND PARBOILED RICES

BY

V. SUBRAHMANYAN, D.Sc., F.I.C., F.N.I.,
A. SREENIVASAN, M.A., D.Sc., A.I.C.

AND

H. P. DAS GUPTA, M.Sc.

Department of Biochemistry, Indian Institute of Science, Bangalore

(Received for publication on 12th April 1938)

(With two text-figures)

It has long been recognised that the incidence of beriberi is greatest among people living on a diet composed largely of polished (highly milled) rice and that the disease can be prevented by the substitution of a sufficiently under-milled rice. It has since been shown by a number of workers [Breaudat, 1912 ; Funk, 1911, 1913 ; Suzuki *et al.*, 1912 ; Schaumann, 1913; Eustin and Scott, 1914 ; Murai, 1914 ; Williams and Saleeby, 1915 ; del Rosario and Maranon, 1919 ; Hofmeister, 1920 ; Wells, 1921 ; Jansen and Donath, 1921, 1926, 1927 ; Odake, 1931 ; van Veen, 1932 ; and others] that the reason for the unpolished rice being a preventative of beriberi is that it contains an active principle originally called ' vitamine ', ' antiberiberine ', ' oridine ', ' oryzanine ', etc., and now known as vitamin B_1 (aneurin) which is localized essentially in the outer layers of the rice grain.

From a large number of analyses of unpolished and polished rices carried out by several workers, it has been shown that, besides vitamin B_1, a considerable part of other essential constituents of the rice grain is also lost during polishing [Ross, 1889 ; Brown and Chiquelin, 1904 ; Thompson, 1908 ; Chamberlain, 1911 ; Fraser and Stanton, 1914 ; Wise and Broomell, 1915 ; Fraps, 1916 ; Reed and Liepsner, 1917 ; Issoglio, 1920 ; Andrade, 1921 ; Pool, 1922 ; Sugimoto *et al.*, 1928 ; Vedder and Feliciano, 1928 ; Borasio, 1930 ; McHargue and Roy, 1931 ; LeClerc, 1932 ; West and Cruz, 1933 ; and several others]. A few workers have also studied the distribution of essential nutritive constituents in the different parts of the rice grain and concluded that most or all of the fats, lipoids, minerals, phytin and vitamin $B(B_1)$ are concentrated in the germ and pericarp of the rice kernel [Suzuki *et al.*, 1907 ; Bernardini, 1911 ; Hamada, 1923 ; Croell, 1927 ; Vedder and Feliciano, 1928 ; Borasio, 1929, 1932 ; West and Cruz, 1933 ; and others].

Although the foregoing observations have shown that almost all the nutritive constituents of rice are localized in the outer layers, yet it has been considered that parboiled rice, even on milling, does not lose much of its nutritive and antineuritic value. Attention was first drawn to the greater antineuritic value of polished, parboiled rice by Braddon [1907], Fletcher [1907, 1909], and Ellis [1909]. Later it was shown by Fraser and Stanton [1910, 1911, 1914] and by McCarrison and Norris [1924] that birds fed on parboiled, polished rice were better protected from polyneuritis than those receiving a diet of polished raw rice. Recently, it was observed by Aykroyd [1932] that milled parboiled rice was richer in vitamin B_1 and in phosphorus than raw rice milled to the same degree. He suggested that, during parboiling, the endosperm may absorb vitamin B_1 at the expense of the germ and pericarp and that polishing would not, therefore, remove the vitamin to the same extent as in the case of untreated rice.

The present investigation relates to a study of (*a*) the chemical changes attendant on parboiling under varying conditions, (*b*) the distribution of essential constituents in the outer layers of the rice grain and (*c*) their changes on (*i*) polishing, (*ii*) parboiling and (*iii*\ parboiling and polishing.

EXPERIMENTAL

Varieties used

Four varieties of paddy, Adt 11, Co 9, Adt 6 and Co 10, obtained through the courtesy of the Paddy Specialist to the Government of Madras, were used for the following studies.

Husking

Husking was done in a specially made wooden hand-huller which was, in some respects, similar to the indigenous stone grinder. It consisted of two circular discs one of which (the bottom one) was stationary while the other (fitted with a handle) was movable. The wearing parts of the two discs contained grooves radiating from the centre. By gentle rotation of the handle, the paddy could be unhusked with practically no loss of the coloured skin or outer coat (' silver skin ').

Polishing

A small rice-polishing machine specially designed for dealing with experimental samples was used for this purpose. The machine consisted of a grindstone inside a drum of finely meshed stout wire. The grindstone and the drum were separated by an annular space of over half an inch into which a known quantity of rice (up to about 300 grms.) could be put. By means of a fly-wheel, driven by the hand, the grindstone and drum could be rotated in opposite directions. As the machine rotated, the outer layers of the rice grains were rubbed off between the two rough surfaces of wire and stone respectively and the millings, thus removed, fell through the wire mesh into a receptacle placed beneath the drum. The milled rice was separately removed after polishing. The millings could be collected and weighed and it was possible to remove any desired percentage weight of millings from a given amount of unmilled rice.

Methods

Moisture, fat, ash and silica were determined by methods recommended by the Association of Official Agricultural Chemists [1935]. Total nitrogen was estimated after wet digestion [Sreenivasan, 1932]. Phosphorus was determined by a modified colorimetric method combining the features of the methods developed by Briggs [1922], Benedict and Theis [1924] and Roe *et al.* [1926]. The procedure consisted in digesting the sample with thirty per cent sulphuric acid and perhydrol followed by addition of ammonium molybdate (aq.) and development of the molybdenum blue colour by reduction with sodium sulphite and hydroquinone.

Chemical composition of raw and parboiled rices

McCarrison and Norris [1924] recorded that the phosphoric acid content of unpolished, parboiled rice was slightly higher than that of unpolished, raw rice. Codd and Peterkin [1933] also stated that the phosphate content of parboiled rice was higher than that of raw rice. Working with six varieties of Ceylon rices, Joachim and Kandiah [1928] found that, except in the fat content (which was slightly lowered), there was, on the whole, no appreciable change in chemical composition as the result of parboiling. Basu and Sarkar [1935] observed that the phosphoric acid contents of parboiled, husked (unpolished) rices were slightly lower than those of sun-dried (raw), husked rices, but that the parboiled rices contained slightly more protein than sun-dried rices from the same varieties. In the following experiments, 100-grm. lots of the four varieties of paddy were steeped in about 250 c.c. of water for a period of forty-eight hours at a temperature of 35°C. The steep water was then drained off and the moist paddy steamed at a pressure of 15 lbs. for about fifteen minutes. The grains were then dried overnight in a current of air at 35-40°C. The hulled rices from these samples were then thoroughly powdered and analysed for their nitrogen and phosphorus contents. The results, as expressed on moisture-free (oven-dry) basis, are given in Table I together with the corresponding values for the raw, hulled (unpolished) rices. The steep water was also analysed in each case for its nitrogen and phosphorus contents.

TABLE I

Nitrogen and phosphorus contents of raw and parboiled rices

Variety	Nitrogen and phosphorus as mg. per 100 grms. of rice				Loss during steeping from 100 grm. of paddy		
	Raw		Parboiled		Nitrogen mg.	Phosphorus mg.	Total ash mg.
	Nitrogen	Phosphorus	Nitrogen	Phosphorus			
Adt 11 . . .	1114	160	1138	160	3·4	*Nil*	11
Co 9 . . .	1239	366	1269	360	4·2	..	6
Adt 6 . . .	1232	501	1265	498	4·6	..	9
Co 10 . . .	1119	351	1132	350	3·0	..	..

The above observations are in agreement with those of Basu and Sarkar [1935]. Loss during steeping was almost negligible.

Effect of parboiling under varying conditions

In parboiling, the time of steeping, the temperature of the steep, renewal of water during the period of steeping, the time of steaming or boiling and the mode of drying given before milling are all variable factors. The methods adopted in different mills are largely empirical. It was thought desirable therefore to prepare specimens of parboiled rice from the same variety by different treatments and to compare their nitrogen and phosphorus contents. Accordingly, 150-grm. lots of paddy (variety Adt 11) were steeped in 400 c.c. of water and parboiled ; the details of treatment are shown in Table II.

TABLE II

Details of parboiling

Treatment No.	Particulars
1	Steeped for 24 hours at 23° and steamed at 7½ lbs. pressure for 15 minutes.
2	Steeped for 24 hours at 35° and steamed at 7½ lbs. pressure for 15 minutes.
3	Steeped for 24 hours at 23° and steamed at 10 lbs. pressure for 15 minutes.
4	Steeped for 24 hours at 35° and steamed at 10 lbs. pressure for 15 minutes.
5	Steeped for 24 hours at 23° and steamed at 15 lbs. pressure for 15 minutes.
6	Steeped for 24 hours at 35° and steamed at 15 lbs. pressure for 15 minutes.
7	Steeped for 48 hours at 23° and steamed at 15 lbs. pressure for 15 minutes.
8	Steeped for 48 hours at 35° and steamed at 15 lbs. pressure for 15 minutes.
9	Steeped for 72 hours at 23° and steamed at 15 lbs. pressure for 15 minutes.
10*	Steeped for 24 hours at 35° and heated at 95° for 25 minutes.
11	Steeped for 24 hours at 35° and steamed (no pressure) for 25 minutes.
12*	Steeped for 4 hours at 50° and heated at 95° for 15 minutes.
13*	Steeped for 2 hours at 70° and heated at 95° for 10 minutes.

*Except in these cases, the steep water was drained off before steaming.

It was observed that in all the cases some of the paddy had burst out after parboiling, thus showing that the grain had been parboiled to the desired extent (as popularly understood) in all the treatments. After parboiling, the paddy was dried in a current of warm air (40°) for a period of about twelve hours and then hulled.

There was not much variation in the yield of the different products after the various treatments, the average percentage yields after parboiling being : paddy, 102·6 ; kernels, 75·8 ; huller bran, 1·2 ; and husk, 25·8, compared with 100, 74·8, 1·3 and 23·8 per cent respectively for the raw paddy. The slightly higher figures obtained in the former case were no doubt due to the parboiled paddy having absorbed some water. The subsequent drying being at a comparatively low temperature, the last traces of moisture could not be removed.

In Table III are given the nitrogen and phosphorus contents (expressed as mg. in 100 grm. of material) of the different products as also the quantities lost in the steep water.

TABLE III

Distribution of nitrogen and phosphorus in the whole paddy, kernel, huller bran and husk

(Results expressed on moisture-free basis)

Treatment	Nitrogen					Phosphorus				
	Paddy	Kernel	Bran	Husk	Loss in steep water (total N in mg.)	Paddy	Kernel	Bran	Husk	Loss in steep water (total P in mg.)
Raw (untreated control).	955	1114 (1096)	835	288	...	110	160 (154)	121	15	*Nil*
1 . . .	950	1135 (1105)	888	272	2·3	109	165 (151)	118	15	*Nil*
2 . . .	952	1154 (1125)	877	265	2·4	97	162 (152)	110	...	...
3 . . .	931	1147 (..)	869	270	1·9	110	170 (161)	106	...	...
4 . . .	940	1132 (1111)	854	274	1·9	113	154 (151)	110	...	...
5 . . .	933	1150 (1092)	850	265	2·6	100	156 (149)	119	...	...
6 . . .	...	1134 (1112)	842	276	2·8	101	158 (132)	...	...	...
7 . . .	929	1140 (1123)	856	269	...	114	154 (144)	99	...	...
8 . . .	940	1149 (1113)	829	258	2·8	104	149 (149)	104	...	...
9 . . .	918	1136 (1108)	899	267	3·4	103	160 (145)	106	...	...
10 . . .	920	... (1105)	812	292	...	110	152 (145)	95	...	...
11 . . .	...	1134 (1127)	...	270	...	108	165 (140)	114	...	...
12 . .	935	1109 (1097)	849	265	3·0	106	148 (148)	102	...	...
13 . .	935	1121 (1106)	824	254	3·0	102	157 (142)	100	...	...

The figures in brackets represent the analytical values obtained after slight polishing (0·5 1·0 per cent) so as to correspond to the brown rice of commerce.

It may be seen (Table III) that there was very little difference between the composition of the samples obtained after various treatments. The figures for huller bran are interesting. Though it represents the layer between the hulls and the kernel and is immediately beneath the husk, yet it is very rich in nitrogen and phosphorus, being more than four-fifths as rich in these constituents as the rice kernel itself. A comparison of the figures for the nitrogen of raw and parboiled rices would show that, in almost all the cases, the latter contain slightly more (2 to 3 per cent) of nitrogen. This is obviously due to a part of the nitrogen from husk passing into the grain during parboiling. The nitrogen content of the husk from parboiled paddy is also less than that from the raw grain. This is no doubt due, in part, to loss by passage into the steep water, but, as already mentioned, the major part of the nitrogen passes into the kernel.

Since parboiling renders the outer coating of the rice kernel tough and therefore less liable to be lost during hulling, it is possible that this may account for the increase in the nitrogen of the kernel on parboiling. Thus, the yield of huller bran from parboiled specimens is somewhat less, but since the percentage nitrogen in the latter case is more and since also huller bran is itself poorer in nitrogen than the rice kernel, this will not account for the extra nitrogen in parboiled rice. The extra nitrogen has therefore been derived only from the husk and indeed the general observation that parboiled rice is darker in colour than raw rice is (as has been further proved in a later section) largely due to some of the colouring matter from the husk passing into the kernel.

The effect of light polishing is rather significant. The nitrogen content of the parboiled product is generally slightly higher and phosphorus content slightly lower than that of the corresponding specimen of raw rice.

Effect of degree of polishing on the nitrogen and phosphorus contents of raw and parboiled rices

Aykroyd [1932] found that, when a sample of unmilled rice is polished to the extent of fifteen per cent by weight, more than two-thirds of the phosphorus in the rice is removed in the millings, whereas, with parboiled rice milled to the same extent, only half the amount of phosphorus is lost. These results have been explained by him as being due to a diffusion of the soluble phosphorus compounds contained in the integuments through the endosperm during parboiling. In view of these observations, it was thought useful to follow the distribution of phosphorus and nitrogen in the different layers of the rice grain and the changes, if any, in this distribution brought about by parboiling. Two varieties of rice (Adt 11 and Co 9) were used for this purpose. Three hundred grm. lots of the unpolished rice, raw as well as parboiled (the latter obtained by soaking for forty-eight hours at 35° followed by steaming at 15 lbs. for 15 minutes), were introduced into the drum of the hand-mill and the latter slowly rotated. At definite stages, the polishings were collected separately and weighed. It was found that by using fairly large quantities of rice in the machine and also by a steady rotation of the fly-wheel, uniform polishing could be effected. That all of the added rice was being polished more or less uniformly was checked from time to time by removing a certain definite number of grains and checking their weight. The polishings were removed in eleven stages until about 75 grm. of millings were obtained in all. Thus, the final rice was milled to nearly twenty-five per cent of its original weight.

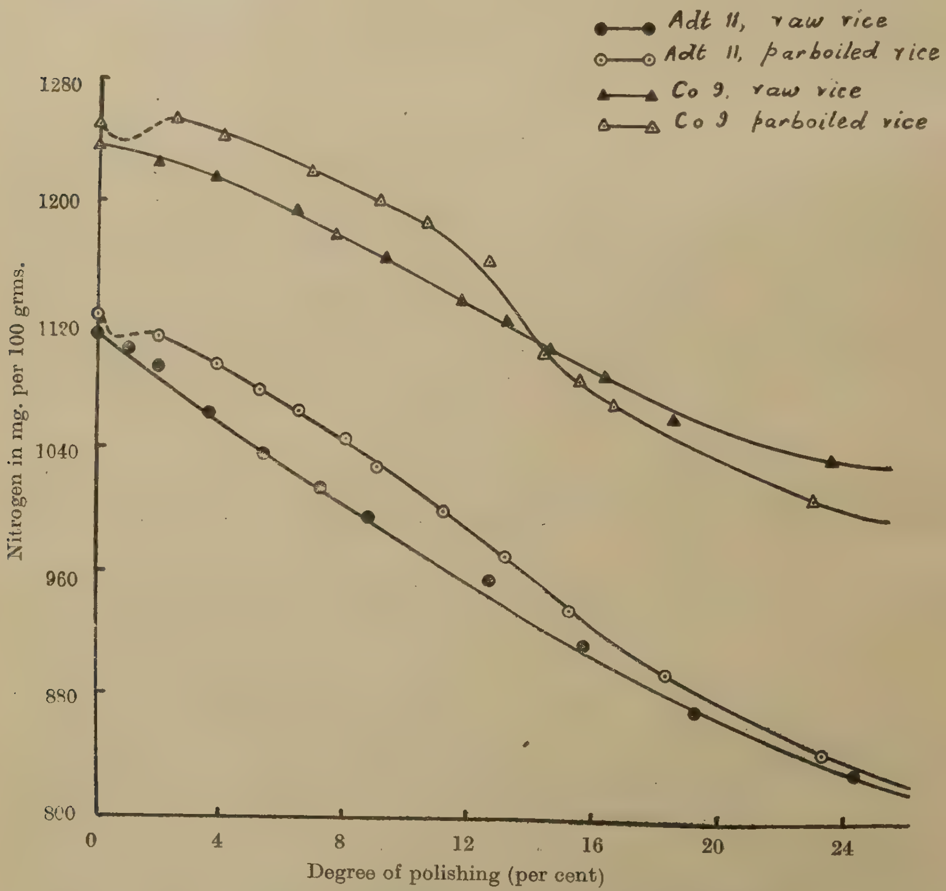


FIG. 1. Changes in nitrogen content of rice on polishing

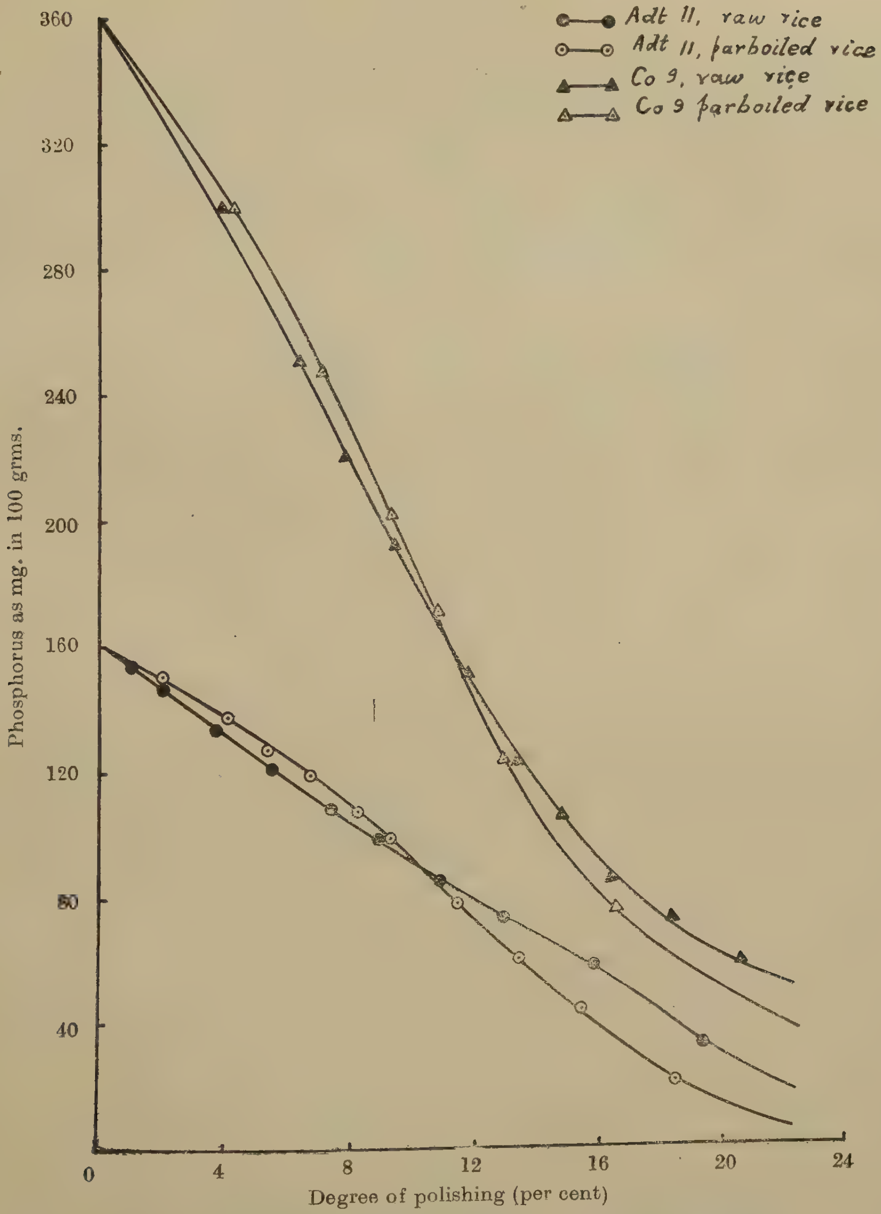


FIG. 2. Changes in phosphorus content of rice on polishing

Each successive sample of the millings was then analysed for its nitrogen and phosphorus contents. From the results were computed the changes in the composition of raw and parboiled rices after different degrees of polishing (Figs. 1 and 2) and the percentage loss of nitrogen and of phosphorus when polished to defferent equal extents (Table IV).

TABLE IV

Percentage loss of nitrogen and phosphorus on polishing

Degree of polishing per cent	VARIETY, Adt 11				VARIETY, Co 9			
	Raw rice		Parboiled rice		Raw rice		Parboiled rice	
	Total N per cent lost	Total P per cent lost	Total N per cent lost	Total P per cent lost	Total N per cent lost	Total P per cent lost	Total N per cent lost	Total P per cent lost
2·0	1·98	8·12	2·37	7·51	0·97	8·74	...	...
3·0	3·03	12·92	3·30	11·67	1·56	13·90	1·60	12·22
5·0	5·33	21·71	4·92	19·50	2·79	24·46	2·23	22·03
7·0	7·57	30·52	6·92	28·08	4·16	35·14	3·86	31·60
9·0	9·73	39·51	9·24	37·74	5·79	45·73	5·09	43·03
11.0	11·81	47·57	11·65	48·47	7·48	55·39	6·67	54·23
13·0	14·13	54·37	14·17	60·13	9·19	64·39	8·66	67·68
15·0	16·16	60·62	16·93	70·50	11·00	72·18	10·75	81·69
18·0	19·30	69·41	20·93	85·50	13·84	79·20	14·21	94·45

It may be seen (Figs. 1 and 2) that with increased milling, both raw and parboiled rices become poorer in nitrogen, the former at a slightly faster rate than the latter. In regard to phosphorus, the effect of milling is still more pronounced. With about ten per cent milling the phosphorus content falls to about half its original value in the case of one variety, and to about one-third in the other. With further milling, the phosphorus content goes down at a still faster rate, until, at about twenty per cent, there is no more than a trace of phosphorus in the final product. It is probable that even this was derived from the small quantities of finely divided bran adhering to the grain.

In ordinary milling practice, the polishing is generally carried to the extent of between ten and fifteen per cent. This would mean that about a third of the nitrogen of the grain and over half to two-thirds of the phosphorus would be lost in the form of polishings.

In some parts of India, the miller gets the entire quantity of the polishings as a part of the payment towards the cost of milling. In such cases, the milling is naturally carried out to between twenty and twenty-five per cent, so that the miller gets a high yield of polishings, and the consumer gets a fine white product, with pleasing appearance but sadly depleted of the valuable constituents of the grain.

A further observation of interest is the difference in response between the two varieties of rice that were experimented with Co 9, which is a coloured rice (the outer kernel being deep brown) is richer in nitrogen and very much more so in regard to phosphorus than the other variety (Adt 11) which is white. As the polishing proceeds, Co 9 loses both phosphorus and nitrogen at a much faster rate than the other variety, thus showing that in the former the two constituents are largely concentrated in the pericarp layers.

There is a popular belief that red rice is more nutritious than ordinary brown or white rice. It is possible that the superior nutritive value of red rice may be due to the greater thickness of its bran layers. Moreover, it is a common observation that although under well-polished conditions, even deeply pigmented red rices can be made to appear white, still under the ordinary conditions of milling that obtain for common (brown) rice, red rices still retain a part of their colour ; it would thus appear that the greater nutritive value of red rices is due to their usually being milled comparatively to a lesser degree. Further work on the chemical composition of different red rices and their nutritive value, as also a histological examination of the thickness of their bran layers, is desirable to substantiate the belief that red rice is more nutritious than common white or brown rice.

Influence of the method of parboiling on the composition of the resulting rice

With a view to determining whether parboiling by different methods affects the change in nitrogen and phosphorus content with milling, some experiments were conducted in which four samples of parboiled rice from the same variety (Adt 11) were polished to about 10 per cent and their nitrogen and phosphorus contents determined (Table V).

TABLE V

Nitrogen and phosphorus contents of parboiled milled rices (Adt 11)
(Results expressed on oven-dry basis)

Details of parboiling	Degree of milling per cent	Nitrogen mg. per 100 grm.	Phosphorus mg. per 100 grm.
Steeped for 24 hours at 23°C. and steamed at 7½ lbs. for 15 minutes	9·5	1015	96
Steeped for 24 hours at 35°C. and steamed at 15 lbs. for 15 minutes	10·0	1010	94
Steeped for 72 hours at 23°C. and steamed at 15 lbs. for 15 minutes	10·8	990	89
Steeped for 4 hours at 50°C. and heated at 95° for 15 minutes	9·5	1006	99

A comparison of the above figures with the corresponding values for raw milled rice (Figs. 1 and 2) shows that in every case the parboiled rice is slightly richer in these constituents than raw rice milled to the same degree. The values for the different parboiled specimens fall within a narrow range. The products vary in their intensity of colouration, those steeped for longer periods followed by autoclaving at higher pressure being darker than those subjected to less drastic treatment. Apart from this, the general chemical effects of parboiling appear to be more or less similar in all the cases.

Distribution of nitrogen and phosphorus in raw and parboiled rice grain

The hulled rice was prepared from the untreated and parboiled specimens of the two varieties (Adt 11 and Co 9) of paddy and from 100 grm. of this was separated, in each case, the germ, bran and endosperm fractions. This was achieved by polishing the grains till there was no brown tinge in the millings and separating the germ fraction from the bran in the mixed polishings by passing through a forty-mesh sieve. The two fractions were then weighed after drying at 100° and their nitrogen and phosphorus contents determined (Table VI).

TABLE VI

Analysis of germ (embryo) and bran (pericarp) of the rice grain

Part of grain	Raw rice			Parboiled rice		
	Wt. per 100 grm. of rice (grm.)	Nitrogen in mg. per 100 grm.	Phosphorus in mg. per 100 grm.	Wt. per 100 grm. of rice (grm.)	Nitrogen in mg. per 100 grm.	Phosphorus in mg. per 100 grm.
Variety Adt 11						
Germ . .	1·2	1710	974	1·3	1642	885
Bran . .	9·3	2372	760	9·2	2279	770
Variety Co 9						
Germ . .	1·4	1772	2230	1·3	1680	2105
Bran . .	11·8	2027	1905	11·5	2036	1983

It may be observed that there is a distinct, though small, difference in the composition of the two fractions obtained from raw and parboiled rices of the same origin and in the relative distribution of the constituents in them.

The germ loses part of its nitrogen during parboiling, probably by diffusion into the bran layers and the endosperm. In a like manner, part of the phosphorus originally present in the embryo moves into the remaining part of the grain.

The results of the relative distribution of nitrogen and phosphorus in the grain, as also the analyses of successive layers of polishings from the rice, had shown that while more than fifty per cent of the phosphorus (in Co 9 as high as 75 per cent) and twenty per cent of the nitrogen are present in the exterior layers, there is at the same time a gradual decrease in the nitrogen and phosphorus contents of successive layers of the grain towards the endosperm. With a view to determining whether these constituents are distributed uniformly in the endosperm portion of the grain, the two varieties of rice (raw) were polished to twenty and thirty per cent respectively of their original weight and the nitrogen and phosphorus contents of the resulting endosperm determined. Polishing could not be carried out further as most of the grains had broken even at thirty per cent polishing. The results are recorded in Table VII.

TABLE VII

Nitrogen and phosphorus contents of highly milled raw rices

Variety, Adt 11			Variety, Co 9		
Polished rice representing percentage of whole grain	Nitrogen in mg. per 100 grm.	Phosphorus in mg. per 100 grm.	Polished rice representing percentage of whole grain	Nitrogen in mg. per 100 grm.	Phosphorus in mg. per 100 grm.
89·5 . . .	975	87	86·8 . .	1123	127
80·0 . . .	840	39	80·0 . .	1046	64
70·0 . . .	662	20	70·0 . .	928	22

It is interesting to note that in the endosperm even as in the pericarp layers, the nitrogen and phosphorus are concentrated chiefly in the exterior layers.

Changes in fats and minerals on parboiling

With a view to finding the changes in fat and mineral contents brought about as a result of parboiling determinations were made, on the two varieties (Adt 11 and Co 9) of rice, raw and parboiled, unpolished as well as polished to five and ten per cent respectively. These results together with the phosphoric acid and protein contents are given in Table VIII.

TABLE VIII

Composition of unmilled and milled raw and parboiled rices (Results on air-dry basis)

Material, description	VARIETY, Adt 11						VARIETY Co, 9					
	Moisture	Fats	Proteins	Ash	P_2O_5	Sio$_2$	Moisture	Fats	Proteins	Ash	P_2O_5	Sio$_2$
Raw, unpolished	10·7	2·26	6·96	1·27	0·37	0·17	10·6	2·25	7·74	2·24	0·84	0·07
Parboiled, unpolished	11·3	2·23	7·11	1·40	0·37	0·26	10·7	2·20	7·93	2·15	0·83	0·15
Raw, polished (5 per cent)	11·4	1·51	6·50	0·41	0·28	0·05	11·3	1·19	7·50	0·70	0·61	...
Parboiled polished (5 per cent)	11·6	1·22	6·76	0·46	0·30	0·07	11·5	1·13	7·70	0·85	0·64	...
Raw, polished (10 per cent)	11·8	0·40	6·16	0·25	0·20	...	11·9	0·82	7·16	0·57	0·43	...
Parboiled polished (10 per cent)	11·8	0·40	6·31	0·35	0·22	...	12·0	0·74	7·44	0·69	0·44	...

It may be observed that as a result of slight (five per cent) polishing parboiled rice preserves more of protein and mineral constituents than the corresponding raw rice. Rice polished to about ten per cent contains scarcely a fifth of the original amounts of these constituents, but it may be noted that the loss of minerals in parboiled polished rice is still comparatively less than in the corresponding raw rice. With fats, however, the reverse would appear to hold true. Thus, during parboiling, the mineral constituents would appear to have moved in part towards the interior, while the fats from the aleurone layers have probably moved outwards. The increased removal of fat during the polishing of parboiled rice should be regarded as favourable. A high fat content leads to rancidity and offensive odours on keeping. Insects are also attracted to the grain. The good keeping quality of highly polished rice is largely due to the removal of fat. If, by careful parboiling and subsequent partial polishing, the fat can be mostly removed, the keeping quality is ensured without having to remove the valuable constituents.

Effect of washing and cooking

McCarrison and Norris [1924] found that washing of rice causes a great loss of mineral ingredients and of the water-soluble antineuritic vitamin. It is believed by these authors that the occurrence of beriberi in areas where people use parboiled rice is due to the prevailing practice of washing the rice prior to cooking by which procedure a large part of the nutritive constituents is lost. The effects of repeated washing and boiling on the vitamin content of ordinary milled rice has also been studied by van Veen [1933, 1934] and Rudra and Bagchi [1933]. With a view to finding out the extent of loss of nitrogen and phosphorus on washing and cooking under ordinary conditions, 10-grm. lots of the raw and parboiled specimens (both polished as well as unpolished) were, in one set of experiments, washed in tap water about half a dozen times and subsequently dried before analysis. In another set, the unwashed rice, in 10-grm. lots, was boiled with excess (about 100 c.c.) of water until the rice cooked to a good consistency after which the excess of the watery portion was drained off and the cooked grains dried for analysis. Table IX gives the percentage loss of nitrogen and of phosphorus in the different cases.

TABLE IX

Percentage loss of nitrogen and phosphorus on washing and on cooking

Description of rice	Nitrogen in rice mg. per 100 grm.	Phosphorus in rice mg. per 100 grm.	Washed rice			Cooked rice		
			Yield(grm.) of washed rice per 100 grm.	Per cent total N lost in wash-water	Per cent total P lost in wash-water	Yield(grm.) of washed rice per 100 grm.	Per cent total N lost in cooked water	Per cent total P lost in cooked water
				Variety, Adt 11				
Raw, unpolished .	1114	160	98	3·3	17·5	98	2·9	13·8
Parboiled, unpolished	1138	160	99	3·5	15·0	98	2·5	11·3
Raw, semi-polished (5 per cent)	1040	123	94	4·3	14·6	95	4·3	14·6
Parboiled, semi-polished (5 per cent)	1082	132	96	3·1	13·6	96	2·8	11·4
Raw, polished (10 per cent)	985	88	93	3·7	18·2	92	8·1	17·1
Parboiled, polished (10 per cent)	1010	94	95	3·4	12·8	95	4·5	12·8
				Variety, Co 9				
Raw, unpolished .	1239	366	99	2·3	18·6	99	1·0	12·6
Parboiled, unpolished	1269	360	99	1·7	14·4	99	1·0	11·1
Raw, semi-polished (5 per cent)	1200	265	93	3·3	18·1	96	2·8	...
Parboiled semi-polished (5 per cent)	1232	280	95	2·9	18·2	97	1·7	...
Raw, polished (10 per cent)	1148	186	91	4·4	21·0	93	5·2	18·6
Parboiled, polished (10 per cent)	1190	194	94	2·9	19·6	94	3·2	17·5

Considerable quantities of nitrogen and of phosphorus are lost both by washing and by cooking. The loss will obviously be greater if the rice is washed prior to cooking, as is practised in many households. The extent of loss of nitrogen or of phosphorus increases with the degree of polishing. It may be noted, however, that in every case the loss is less with the parboiled specimens. This may be due in part to the fact that parboiling toughens the outer layers of the rice grain, and in part to the circumstance that some of the constituents move down into the interior of the grain during parboiling. The loss in nutritive constituents as a result of cooking with excessive amounts of water is generally recognised and indeed, it has been the practice in most households to use only the minimum amount of water for cooking. The loss resulting from the washing of rice is not so well known ; washing is resorted to generally with a view to removing dirt and adhering bran and is a wasteful process especially when reckoned together with the losses on polishing.

As may be expected, the percentage loss of nitrogen and phosphorus increases with the degree of polishing. Further, the loss as a result of washing is often greater as compared to that on cooking. This is doubtless due to a part of the constituents being re-absorbed by the rice grains in the latter case.

INFLUENCE OF PARBOILING ON THE MILLING QUALITY OF RICE

In milling paddy by the aid of power-driven rice hullers, a certain percentage of the grains gets broken in the operation. The factors which contribute to high milling quality are yet ill-defined although, recently, Stahel [1935] has examined experimentally some of the factors, like the moisture content of the paddy, the maturity of the crop at harvesting, the formation of sun-cracks and the harvesting practices, which influence breakage of rice in milling.

The process of parboiling not only loosens the husk which is therefore more easily shelled from the kernel, but it also toughens the rice permitting of more severe milling. This superior milling quality of parboiled rice has been generally recognised [Ishaq, 1920 ; Charlton, 1923 ; Douglas, 1930 ; and Jones and Taylor, 1935], and indeed it has been the practice with millers to parboil the mealy and soft varieties of paddy which would otherwise break easily in milling.

The following relates to a study of the extent to which parboiling to varying extents and by different treatments affects the milling quality of rice, its colour, keeping and cooking qualities and other physical characteristics.

Varieties used

Four varieties of paddy, Adt 11, Co 9, Adt 6 and Hmawbi A 16-34, were used for the study. The last was a long-grained variety while the others were all medium-grained.

Parboiling methods

Soaking.—One hundred grm. lots of the paddy in conical flasks of one litre capacity were first washed a few times with water. The 'wind rice' which floated on top were removed and the paddy was then kept submerged in about 250 c.c. of water, either at room temperature or at other controlled temperatures for the desired lengths of time. The flasks were then removed and the excess of water was drained off before steaming.

Steaming.—The soaked paddy was steamed under pressure, the steam being generated from an autoclave. The pressure of the steam was adjusted between 0 and 15 pounds as required by regulating the gas supply for heating. Steaming was done for definite lengths of time.

Boiling.—Here the paddy was soaked as before at a definite temperature for the desired length of time after which the flask containing the soaked paddy was heated with the water over a small flame and kept at a high temperature or near boiling for a definite interval after which the water was drained off before drying. This method of parboiling, called the *josh* (boiling) method [Ishaq, 1920] is the one usually adopted in households and in small-scale operations.

Drying.—After the paddy had been parboiled by steaming or boiling, it was dried in a chamber through which a slow draught of warm (35-40°C.) air was drawn. Drying was done overnight, *i.e.*, for a period of twelve to fifteen hours. Sun-drying was not resorted to as it was thought best to do the drying under controlled and comparable conditions.

Shelling and milling tests

The parboiled as well as the corresponding raw samples (untreated checks, also 100 grm. of the paddy) were shelled in the hand-huller described previously. The kernels were then separated from the hulls and the whole kernels picked out from the former and weighed. This was recorded as the yield (per 100 grm. of paddy) of head rice on hulling. The whole kernels were then put into the milling machine and polished till about ten per cent of these were removed as millings. From the polished rice thus obtained were separated once again the whole kernels from those which had got broken during the polishing and their weights taken. This was recorded as the yield of head rice on milling.

Results

Untreated (*check*).—In Table X are given the yields of head rice and broken rice on hulling 100 grm. of the raw untreated paddy and also the yield of head rice on milling to ten per cent of the weight of the whole kernels.

TABLE X

Yield of head rice from untreated paddy

Variety	Yield of hulled head rice from 100 grm. of paddy (grm.)	Yield of 'screen rice' or broken rice (grm.)	Yield of head rice on milling (grm.)
Adt 11	61·0	14·6	47·0
Co 9	59·4	20·1	45·8
Adt 6	39·2	39·0	26·4
Hmawbi A 16-34	39·4	37·0	23·8

Parboiled specimens.—It was observed that from any particular variety of paddy, the total yield comprising both head rice and broken rice was almost the same as in the corresponding raw paddy, irrespective of the treatment of parboiling. The proportions of the two products were however altered by the method of parboiling. Invariably higher yields for head rice were obtained as a result of parboiling. The particulars of parboiling, together with the percentage increase over check on hulling and milling are given under four heads in Tables XI-XIV. The first head refers to those for which the period of steeping was twenty-four hours and the temperature of steeping either 23° or 35°C. The time of steaming as also the pressure of steam were varied and are shown in Table XI. In the second group (Table XII), the period of steeping was forty-eight hours and the temperature 23°C. or 35°C. while the time and pressure of steaming were varied as before. In the third (Table XIII), the time and pressure of steaming were varied as before, but the steeping was done for a period of seventy-two hours at 23°C. or at 35°C. The last group refers to the 'boiling' process, the details being given in Table XIV.

Table XI

Yield of parboiled rice, steeped for 24 hours

Particulars of parboiling	Per cent increase over check in head rice on hulling				Per cent increase over check in head rice on milling			
	Adt 11	Co 9	Adt 6	A 16-34	Adt 11	Co 9	Adt 6	A 16-34
1. Steeped for 24 hours at 23°C. and steamed at 0 lbs. for 15 minutes	5·1	2·7	...	...	4·7	—21·2	...	...
2. Steeped for 24 hours at 23°C. and steamed at 0 lbs. for 30 minutes	11·8	—0·7	—10·2	30·5	1·3	—25·3	—16·3	46·2
3. Steeped for 24 hours at 23°C. and steamed at 0 lbs. for 45 minutes	...	...	14·8	21·8	...	...	9·8	38·6
4. Steeped for 24 hours at 23°C. and steamed at 10 lbs. for 5 minutes	...	...	10·9	44·2	...	...	—17·4	54·6
5. Steeped for 24 hours at 23°C. and steamed at 10 lbs. for 10 minutes	...	4·7	...	63·4	...	12·7	...	97·1
6. Steeped for 24 hours at 23°C. and steamed at 10 lbs. for 20 minutes	14·1	1·9	59·9	40·1	2·1	—14·4	51·5	63·8
7. Steeped for 24 hours at 23°C. and steamed at 15 lbs. for 15 minutes	...	18·7	27·5	70·0	...	9·6	23·9	120·0
8. Steeped for 24 hours at 23°C. and steamed at 15 lbs. for 20 minutes	...	21·2	33·7	55·3	...	13·5	29·5	97·9
9. Steeped for 24 hours at 35°C. and steamed at 0 lbs. for 15 minutes	13·1	10·3	35·2	...	11·5	7·4	52·3	...
10. Steeped for 24 hours at 35°C. and steamed at 0 lbs. for 30 minutes	...	24·2	...	...	...	6·1	...	...
11. Steeped for 24 hours at 35°C. and steamed at 0 lbs. for 45 minutes	5·9	...	—9·6	...	...	...	—27·8	...
12. Steeped for 24 hours at 35°C. and steamed at 5 lbs. for 15 minutes	15·1	23·5	50·7	...	13·6	8·7	51·1	...
13. Steeped for 24 hours at 35°C. and steamed at 5 lbs. for 20 minutes	21·6	...	52·3	62·9	20·0	...	43·9	102·8
14. Steeped for 24 hours at 35°C. and steamed at 5 lbs. for 30 minutes	...	22·7	60·7	52·3	...	10·7	60·6	79·0
15. Steeped for 24 hours at 35°C. and steamed at 15 lbs. for 5 minutes	...	34·7	12·3	55·3	...	29·7	6·4	88·2
16. Steeped for 24 hours at 35°C. and steamed at 15 lbs. for 15 minutes	20·3	...	...	69·5	25·9	...	...	110·1
17. Steeped for 24 hours at 35°C. and steamed at 15 lbs. for 20 minutes	22·9	32·5	54·3	70·0	25·3	27·1	46·6	119·3

TABLE XII

Yield of parboiled rice, steeped for 48 hours

Particulars of parboiling	Per cent increase over check in head rice on hulling				Per cent increase over check in head rice on milling			
	Adt 11	Co 9	Adt 6	A 16-34	Adt 11	Co 9	Adt 6	A16-34
18. Steeped for 48 hours at 23°C. and steamed at 10 lbs. for 5 minutes	5·2	14·5	58·2	...	7·7	18·8	45·4	...
19. Steeped for 48 hours at 23°C. and steamed at 10 lbs. for 20 minutes	20·3	29·6	58·2	39·6	14·3	21·8	52·3	66·4
20. Steeped for 48 hours at 35°C. and steamed at 0 lbs. for 15 minutes	1·74	16·2	54·3	55·6	16·6	9·2	53·8	85·7
21. Steeped for 48 hours at 35°C. and steamed at 0 lbs. for 45 minutes	14·8	...	59·4	35·1	8·3	...	17·4	52·9
22. Steeped for 48 hours at 35°C. and steamed at 5 lbs. for 15 minutes	24·6	26·3	78·6	62·4	20·8	14·4	69·7	81·8
23. Steeped for 48 hours at 35°C. and steamed at 5 lbs. for 20 minutes	15·1	33·7	76·0	...	6·4	18·1	96·9	...
24. Steeped for 48 hours at 35°C. and steamed at 5 lbs. for 30 minutes	12·1	19·5	52·3	70·0	5·1	9·4	52·6	92·8
25. Steeped for 48 hours at 35°C. and steamed at 15 lbs. for 15 minutes	22·9	26·3	72·7	15·2	25·5	6·9	73·5	...

TABLE XIII

Yield of parboiled rice, steeped for 72 hours

Particulars of parboiling	Per cent increase in head rice on hulling				Per cent increase in head rice on milling			
	Adt 11	Co 9	Adt 6	A 16-34	Adt 11	Co 9	Adt 6	A 16-34
26. Steeped for 72 hours at 23°C. and steamed at 10 lbs. for 10 minutes	...	27·1	70·2	...	...	30·8	57·5	...
27. Steeped for 72 hours at 23°C. and steamed at 10 lbs. for 20 minutes	...	27·1	33·9	...	...	12·2	29·5	...
28. Steeped for 72 hours at 23°C. and steamed at 15 lbs. for 5 minutes	3·9	21·2	32·6	63·9	—4·7	10·5	32·6	97·5
29. Steeped for 72 hours at 23°C. and steamed at 15 lbs. for 20 minutes	20·0	9·4	78·6	51·0	10·9	—3·5	90·2	68·0
30*. Steeped for 72 hours at 23°C. and steamed at 15 lbs. for 5 minutes	17·1	29·6	47·2	70·5	15·3	8·9	24·2	108·4
31*. Steeped for 72 hours at 23°C. and steamed at 15 lbs. for 20 minutes	14·4	8·4	79·8	56·0	8·3	—3·5	87·1	100·4
32. Steeped for 72 hours at 35°C. and steamed at 15 lbs. for 10 minutes	13·1	26·3	...	...	15·3	17·6	...	...
33. Steeped for 72 hours at 35°C. and steamed at 15 lbs. for 15 minutes	...	28·5	67·8	47·2	...	15·9	71·2	84·8
34*. Steeped for 72 hours at 35°C. and steamed at 15 lbs. for 10 minutes	17·1	31·3	...	...	18·3	17·9	...	...
35*. Steeped for 72 hours at 35°C. and steamed at 15 lbs. for 15 minutes	...	29·3	70·8	20·6	...	18·3	71·2	47·9

* Steep water was removed twice a day in these cases.

TABLE XIV

Boiling process

Particulars of parboiling	Per cent increase over check in head rice on hulling				Per cent increase over check in head rice on milling			
	Adt 11	Co 9	Adt 6	A 16-34	Adt 11	Co 9	Adt 6	A 16-34
36. Steeped for 6 hours at 45°C. and steamed at 15 lbs. for 15 minutes	19·2	21·2	64·5	66·5	20·8	11·8	56·1	106·3
37. Steeped for 2 hours at 70°C. and boiled for 15 minutes	15·7	15·3	66·3	64·9	17·0	9·2	54·5	86·6
38. Steeped for 30 minutes at 70°C. and steamed at 15 lbs. for 15 minutes	15·1	17·8	73·5	67·2	20·8	...	59·5	110·5

The following general conclusions may be drawn in regard to the effect of parboiling on milling quality :—(1) Other factors being constant, the longer the time of steeping, the better the milling quality. (2) Steaming for too short a period or for too long a time results in greater breakages than steaming for a moderate length of time. (3) Time of steeping can be advantageously reduced by using a higher temperature for steep water and, likewise, time of steaming can, within limits, be reduced by using steam at higher pressure. Care should be taken, however, to see that in steaming, especially under pressure, the steam is allowed to play uniformly throughout the mass of the paddy.

It is difficult to single out a particular treatment of parboiling which can be said to be the best in regard to milling quality, with respect to all varieties of paddy. It may, nevertheless, be stated that soaking for forty-eight to seventy-two hours either at ordinary temperatures or preferably at about 35°C. followed by steaming for 15 minutes at 110° (15 lbs. pressure) gives uniformly good results with all the varieties. Such a treatment does not, however, yield a product of good quality as (*a*) the colour of the grain becomes relatively darker, (*b*) the fermentation during steeping results in the production of foul odours and (*c*) steeping at 35°C. for long periods especially in flowing water results in germination and the attendant loss of head rice. Some of the valuable constituents may also be lost in the steep water. In regard to parboiling by boiling it may be seen that comparatively good results are obtained in almost all the cases. It will indeed be a considerable saving of time, as the initial period of soaking by the other methods, extending over two to three days, can be avoided. Besides, the fermentation changes which occur during prolonged steeping [Charlton, 1923] are avoided. The colour of the rice obtained by this method is very much less attractive than that of the other preparations.

Yield of head rice with different degrees of polishing

One hundred grm. lots of four different varieties of rice, raw as well as parboiled, were polished to varying extents and the percentage yield of head rice determined in each case (Table XV).

TABLE XV

Milling qualities of short and long grain varieties

Rice, description	Degree of milling (per cent) 2	5	10	15	20	25
	Percentage yield of head rice					
Adt 11 (white medium-grained) raw . . .	93	84	76	64	53	34
Adt 11 (white medium-grained) parboiled . .	95	91	83	65	49	30
Hmawbi (white long-grained) raw	69	52	43	31	29	..
Hmawbi (white long-grained) parboiled . . .	96	86	78	59	40	..
Co 9 (red medium-grained) raw	..	86	80	69	56	40
Co 9 (red medium-grained) parboiled . . .	..	90	86	72	55	34
'Kagge' (red long-grained) raw	67	67	59	37	34	23
'Kagge' (red long-grained) parboiled . . .	..	88	82	59	42	26

It may be seen that, in all the cases, the yield of head rice decreases rapidly with increased milling. With the same variety the parboiled grain generally mills better than raw rice. If the polishing is extended beyond twenty per cent, the parboiled rice breaks up even more than raw rice and yields a lower percentage of head rice. The milling qualities of long-grained varieties are greatly improved by parboiling.

Rates of milling of raw and parboiled rice

Two hundred grm. lots of raw and parboiled rice from two varieties (Adt 11 and Co 9) of paddy were milled in the hand-machine, the fly-wheel being rotated at the rate of fifty to sixty revolutions per minute. At definite intervals, milling was stopped and the polishings collected and weighed. The percentage weight of millings removed at the end of definite periods are shown in Table XVI.

TABLE XVI

Rate of milling of raw and parboiled rice

Source of rice	Time in minutes 5	10	20	30	50
	Percentage of millings				
Adt 11 (raw) . .	2·8	6·0	10·9	15·0	19·4
Adt 11 (parboiled) . .	2·0	5·7	9·0	13·1	17·2
Co 9 (raw) . . .	3·2	5·9	11·6	16·2	21·3
Co 9 (parboiled) . .	2·4	4·8	9·7	14·0	18·4

It may be observed that the rate of milling decreases with time. The percentage of polishings removed from the parboiled rice at any particular time is generally less than that from raw rice. This is no doubt due to the outer coats having been toughened during parboiling.

Observations on colour

As already observed, parboiled rice is translucent and generally of a straw-yellow colour. The translucence is due to the gelatinisation of starch in the superficial layers of the endosperm ; in some cases, the gelatinisation extends well into the interior. In the above experiments, it was noticed that, even with the same variety, the colour of the parboiled specimens showed varying shades of yellow to amber depending on treatment. In general, short periods of soaking at low temperatures, as also short periods of steaming, produced the minimum discolouration. But it is difficult to say whether such preparations were well parboiled. Specimens which were kept soaked at high temperatures like 60°C. and 70°C., even if only for very short periods of time, were generally coloured deepest after parboiling. Renewal of steep water from time to time considerably lightened the colour of parboiled rice.

A further observation of interest was that the colour of the hull (glume) also appeared to determine the extent of colouration on parboiling. Thus, Adt 11 had a hull of a straw-yellow colour while Adt 6 had a dark brown hull. The raw (unpolished) rices were of about the same colour ; but the parboiled rice prepared out of Adt 11 was always of a lighter shade than that from Adt 6. The steep water from the former at the end of forty-eight or seventy-two hours was also lighter in colour than from the latter. In a like manner, Co 9 paddy had a pale yellow husk, while the 'Kagge' paddy had a dark brown, almost black, husk. The colour of the parboiled rice from Co 9 was lighter than that from the 'Kagge' variety. It was further observed that the inside of the husk from parboiled rice was generally darker in colour than that from raw rice. This showed that the colouring matter had moved into the interior. These observations, together with the previous evidence that part of the husk material is fixed on to the grain during parboiling, would show that the colour of husk is an important factor in determining the colour of parboiled rice.

General discussion

The results of the present enquiry would show that the parboiled rice is generally richer in both nitrogen and phosphorus than raw rice polished to the same degree. The difference is not however very considerable, and indeed, even parboiled rice loses heavily especially in regard to phosphorus, when polished to a high degree. On the other hand, it is well known that parboiled rice does not improve very much in colour unless it is polished to a considerable extent (about twenty-five per cent). In view of this and the fact that in many parts of India, the poorer classes are the chief consumers of parboiled rice, the hulled, parboiled product is either not polished at all, or, at any rate, only to a small extent (four to five per cent), while in the case of raw rice, polishing is generally carried out to a much further extent (fifteen to twenty per cent). It would thus be seen that the parboiled rice, as available in the market, is generally very much richer in nitrogen and phosphorus than polished raw rice.

The observations of Aykroyd [1932] and of Acton, Ghosh and Dutt [1933] on the effect of parboiling and milling on the vitamin B_1 content of rice as assessed by the method of Chick and Roscoe [1929] and by the Spruyt's [1930] colorimetric method, respectively, would suggest a definite penetration of the vitamin from the pericarp layers into the endosperm. This has also been indicated by Douglas [1930], Codd and Peterkin [1933] and others. From the present study, it would appear that the somewhat greater protein and phosphorus contents of parboiled rice decrease with increased milling, until, with a high degree of milling, parboiled rice is not in any way superior to raw rice. It is possible that, likewise, the higher vitamin B_1 content of parboiled rice would decrease with very high milling, but further work is needed to verify this. The extent, to which parboiling preserves the vitamin B_1 and together with it, the other essential nutritive constituents of rice on polishing, would no doubt depend on the variety of rice and in particular on the thickness of its bran layer and on the extent to which the rice has been parboiled.

It has been stated by a number of workers (Fraser and Stanton, 1914 ; Andrade, 1921 ; Pool, 1922, ; Vedder and Feliciano, 1928 ; and others) that the occurrence of the antineuritic vitamin B_1 is proportional to the amount of phosphate present and that therefore the latter would form a useful measure of the former. It has even been suggested [Contardi, 1932 ; Belfanti, 1932 ; Cuboni, 1934 ; etc.] that the condition usually ascribed to a lack of the so-called vitamin B_1 is really due to an insufficiency of the phosphatase and phytase enzymes which occur largely in the polishings and that the enzymic complex is in all probability identical with vitamin B_1. The results of Aykroyd's [1932] investigations would however show that, while the phosphoric acid content may be an index of the vitamin B_1 content of raw rice, such need not be the case with parboiled rice. Careful determinations of the vitamin B_1 values of different samples of raw and parboiled rices milled to different degrees and a comparison of the results with their phosphoric acid contents is necessary, before anything definite can be said as to whether phosphoric acid content would serve as a guide to vitamin B_1 value.

McCarrison [McCollum and Simmonds, 1929] found in unhulled rice vitamin A which prevents eye afflictions. McCarrison [1923] has later shown that the vitamin A which is present in raw paddy or rice is destroyed in great part during the parboiling of paddy and that pigeons fed exclusively on parboiled rice develop symptoms of ophthalmia. McCarrison and Norris [1924] confirmed the above observations and have further shown that the boiling and steaming of paddy (parboiling) with subsequent sun-drying, reduces its nutritive value and that it is related to loss of vitamin A and B (B_1) consequent on the action of heat and oxidation. Takahashi and Lim [1930] isolated a crystalline sterol from the unsaponifiable fraction of rice oil and found that these sterol crystals were antirachitic on irradiation. Since parboiling reduces the fat content of rice, it is probable that the antirachitic activity of the sterols may be affected. It would appear from the above that the influence of parboiling on the vitamin content of the grains has to be more thoroughly investigated and conditions determined for their maximum conservation.

The high increase in the yield of head rice on parboiling is a distinct item of advantage to the miller, especially when the soft, the kar or short duration and the long-grained varieties (which are known to possess poor milling qualities) have to be marketed. The influence of the mode of drying of parboiled paddy on the milling quality has not been adequately investigated, but there is some evidence to show that the drying has to be done with care. Over-drying and under-drying affect the milling quality. The superior milling quality of parboiled rice together with its other desirable qualities should make the production and use of this article more extensive than has been the case so far. It is true that parboiled rice of commerce has a flavour (to which some object) and an unattractive colour. These can no doubt be improved and, indeed, parboiled rice prepared properly has a pleasing flavour. The bad flavour noticed in some of the bazaar specimens is due to the fact that bad water had been used in the steeping process or that the same water had been used over and over again. In such cases, foul odours are developed on account of fermentation changes brought about mainly by anaerobic organisms. Charlton [1923] has investigated this question and recommends that the fermentation can be checked by the addition of calcium acid sulphite to the steep water or preferably by raising the temperature of the steep.

As regards the colour of parboiled rice, the present investigation has definitely shown the nature of some at least of the factors responsible for colouration. Hitherto the opinion of millers on the factors causing the colour of parboiled rice has been highly contradictory [Charlton, 1923], but in the light of the present observations, it should be possible, by using methods and equipment well suited to the preparation of good parboiled rice, to obtain a product of uniform light colour.

The cooked parboiled rice is nearly as white as cooked raw rice and has a much better consistency. Some trials were conducted with a view to comparing the cooking qualities of raw and parboiled rices, unpolished as well as polished. It was observed that the polished specimens cooked sooner than the unpolished ones and that in either case, the parboiled rice required longer cooking. The 'rice water' or gruel from the unpolished specimens were thinner than from the raw ones, while as between raw and parboiled rice, the raw specimens gave a thicker gruel. The parboiled cooked rice also retained its consistency and shape, whereas the raw rice, especially when polished, cooked to a soft mass. Parboiled cooked rice also keeps better under water, but otherwise it stiffens on merely keeping. The nature of the changes which the starch and protein constituents undergo during parboiling are under investigation.

SUMMARY

1. As the result of parboiling, the total nitrogen content of hulled rice is increased slightly (to the extent of two to three per cent) while the phosphorus content remains practically unaffected. The high nitrogen content of parboiled (hulled) rice is due to a part of the nitrogen in the husk being fixed on to the grain during parboiling.

2. Only insignificant quantities of nitrogen or of phosphorus pass into the steep water used prior to parboiling.

3. Variations in the time and temperature of steeping and of steaming or boiling during parboiling of paddy does not result in appreciable changes in the nitrogen or phosphorus contents of the husk, huller bran and rice (kernel) of the paddy. On the other hand, these two factors do affect the colour and odour of parboiled rice. The colour is derived from the husk and the odour largely through fermentation during steeping. Both of these undesirable features can be reduced to a minimum by maintaining a continuous flow of the steep water, or, at any rate, changing it frequently.

4. Comparison of specimens of raw and parboiled rices milled to different degrees would show that with the same degree of milling, parboiled rice is usually richer in nitrogen and in phosphorus than raw rice. With increased milling, the difference tends steadily to diminish until, at ten to fifteen per cent, the nitrogen and phosphorus contents are more or less the same.

5. Study of the distribution of nitrogen and of phosphorus in the germ (embryo), bran (pericarp) and endosperm fractions of the rice (raw) grain has shown that more than 50 per cent of the phosphorus and twenty per cent of the nitrogen are localized in the former two fractions, which are generally completely lost during milling. On parboiling, a part of the nitrogen and of the phosphorus originally present in the germ is transferred to the endosperm.

6. Examination of the outer layers of the endosperm of the rice grain has shown that, even in the endosperm, the protein and mineral constituents are concentrated in the outer layers and decrease rapidly towards the interior.

7. Parboiled rice has a higher ash content than raw rice polished to the same extent. Both raw and parboiled rices contain, however, only traces of these mineral constituents when polished to beyond ten per cent of their original weight.

8. On washing repeatedly parboiled rice, whether polished or unpolished, loses less of nitrogen or of phosphorus than raw rice polished to the same extent. In a like manner comparatively less of water-soluble constituents pass out in the 'rice water' on cooking parboiled rice.

9. The milling quality of rice varieties is greatly improved by parboiling. Between thirty and hundred per cent more of head rice is yielded with the different varieties.

10. The different conditions relating to steeping and steaming affect the yield of head rice both before and after milling. Speaking generally, soaking for forty-eight to seventy-two hours at 35°C. followed by steaming at 15 lbs. for fifteen minutes gives uniformly satisfactory results. Steaming for longer periods results in increased breakages.

11. As the milling is continued beyond fifteen to twenty per cent, the yield of head rice drops suddenly to less than forty per cent. At this stage, parboiled rice begins to break up rapidly, so that the yield of head rice is even less than from raw rice.

12. Long-grained varieties of rice, which do not generally mill well when raw, improve considerably on parboiling.

13. The rate of milling being the same, the percentage of polishing removed from parboiled rice is much less than from raw rice.

14. The significance of the foregoing observations in relation to the comparative nutritive values of raw and parboiled rices and the nature of the factors responsible for the colour of parboiled rice are discussed.

ACKNOWLEDGMENTS

We tender our best thanks to the Imperial Council of Agricultural Research for a personal grant to one of us (A. S.). Our thanks are also due to Mr. K. Ramiah, M.Sc., Dip. Agri. (Cantab), L. Ag., formerly Paddy Specialist to the Government of Madras, for his kind interest and for the supply of most of the paddy samples used in this work.

REFERENCES

Acton, H. W.; Ghosh, S. and Dutt A. (1933). *Ind. J. Med. Res.* **21**, 103

Andrade, C. D. (1921). Cited from *Chem. Abstr.* **15**, 2514

A. O. A. C. (1935). Methods of Analysis

Aykroyd, W. R. (1932). *J. Hygiene* **22**, 184

Basu, K. P. and Sarkar, S. N. (1935). *Ind. J. Med. Res.* **22**, 759

Belfanti, S. (1932). Cited from *Chem. Abst.* **26**, 174

Benedict, S. R. and Theis, R. C. (1924). *J. Biol. Chem.* **61**, 63

Bernardini, L. (1911). *Atti Acad. Lincei* **21**, 283 (Cited from *Chem. Abst.* **6**, 1171 : 1912)

Borasio, L. (1929). *Giorn. Risicoltura*, **19**, 69 ; 131 (Cited from *Chem. Abst.* **24**, 1884 ; 1677 : 1930)

——— (1930). *Giorn. Risicoltura* **20**, 71 ; 88 (Cited from *Chem. Abst.* **24**, 4567 ; 4557 : 1930)

——— (1932). *Giorn. Risicoltura* **22**, 111 (Cited from *Chem. Abst.* **28**, 1787 : 1934)

Braddon, W. L. (1907). ' The Cause and Prevention of Beriberi ', London : Rabman Ltd.

Breaudat, L. (1912). *Bull. Soc. Path. Expt.* **4**, 498

Briggs, A. P. (1922). *J. Biol. Chem.* **53**, 13

Brown and Chiquelin, (1904). *Lousiana Agric. Expt. Stn.* (*Ser. 2*), *Bull.* **77**

Chamberlain, W. P. (1911). *Phil. J. Sci.* **6**, 133

Charlton, J. (1923). *Agric. Res. Inst., Pusa Bull.* **146**

Chick, H. and Roscoe, M. H. (1929). *Biochem. J.* **3**, 498

Codd, L. E. W. and Peterkin, E. M. (1933). *Brit. Guiana Dept. Agric. Rice Bull.* **1**

Contardi, A. (1932). Cited from *Chem. Abst.* **26**, 174

Croell, H. M. (1927). *Illinois Agric. Expt. Stn. Rept.* p. 263

Cuboni, E. (1934). Cited from *Chem. Abst.* **28**, 3763

del Rosario, M. V. and Maronon, J. (1919). *Phil. J. Sci.* **15**, 221

Douglas, C. E. (1930). *Empire Marketing Board, Report No.* **32**

Eijkman, C. (1897). *Virshow's Arch.* **148**, 523

Ellis, W. G. (1909). *Brit. Med. J.* **2**, 935

Eustin, A. C. and Scott, L. C. (1914). *Biochem. Bull.* **3**, 466

Fletcher, W. (1907). *Lancet* **1**, 1776

——— (1909). *J. Trop. Med. and Hyg.* **12**, 127

Fraps, G. S. (1916). *Texas Agric. Expt. Stn. Bull.* **191**, 5

Fraser, H. and Stanton, A. T. (1910). *Phil. J. Sci.* **5**, 55

——— (1911). *Studies from the Inst. for Med. Res., F. M. S. No.* **12**

——— (1914). *Lancet* **186**, 96

Funk, C. (1911). *J. Physiol.* **43**, 395

——— (1913). *Pharm. J.* **89**, 351

Ghosh, S. and Dutt, A. (1933). *Ind. J. Med. Res.* **20**, 863

Hamada, M. (1923). *J. Chem. Soc. (Japan)* **44**, 68

Hofmeister, F. (1920). *Biochem. Zeit.* **103**, 218

Ishaq, A. R. (1920). *Bombay Dept. Agric. Bull.* **99**

Issoglio, G. (1920). Cited from *Chem. Abst.* **14**, 1168

Jansen, B. C. P. (1921). Cited from *Chem. Abst.* **15**, 2659

Jansen, B. C. P. and Donath, W. F. (1926). *Chem. Weekblad.* **23**, 201

—————————— (1927). Cited from *Chem. Abst.* **21**, 2150

Joachim, A. W. R. and Kandiah, S. (1928). *Trop. Agric. (Ceylon)* **70**, No. 2

Jones, J. W. and Taylor, J. W. (1935). *U. S. Dept. Agric. Circ.* **340**

LeClerc, J. A. (1932). *Cereal Chem.* **9**, 600

McHargue, J. S. and Roy, W. R. (1931). *Amer. J. Physiol.* **99**, 221

McCarrison, R. (1923). *Ind. J. Med. Res.* **11**, 323

McCarrison, R. and Norris, R. V. (1924). *Ind. Med. Res. Mem.* **2**

McCollum, E. V. and Simmonds, N. (1929). 'The Newer Knowledge of Nutrition', p. 115

Murai, T. (1914). *J. Pharm. Soc. (Japan)*, No. 386

Odake, S. (1931, 1). *Proc. Imp. Acad. (Tokyo)* **7**, 102

——— (1931, 2). *Chem. Ztg.* **2**, 2179

Pool, J. F. A. (1922). *Pharm. Weekblad.* **59**, 1079

Reed, J. B., and Liepsner, F. W. (1917). *U. S. Dept. Agric. Bull.* **570**

Roe, J. H., Irish, O. J. and Boyd, J. I. (1926). *J. Biol. Chem.* **67**, 579

Ross (1889). *Lousiana Agric. Expt. Stn. Bull.* **24**

Rudra, M. N. and Bagchi, K. N. (1933). *Patna J. Med.* **8**, 161

Schaumann, A. (1913). *Trans. Soc. Trop. Med. & Hyg.* **5**, 59

Spruyt, J. P. (1930). *Meded. van den dienst der Volks Nederl. Ind.* **19**, 46 (also *Chemische Weekblad* **27**, 298)

Sreenivasan, A. (1932). *Ind. J. Agric. Sci.* **2**, 525

Stahel, G. (1935). *Trop. Agric. (Trinidad)* **12**, 255

Sugimoto Higuchi Momoydea and Tanaka (1928). Cited from *Chem. Abst.* **22** 2773

Suzuki, S., Yoshimura K. and Takaishi, M. (1907). *Bull. Coll. Agric. Tokyo Imp Univ.* **7**, 503

Suzuki, U. Shimamura, T. and Odake, S. (1912). *Biochem. Zeit.* **43**, 89

Takahashi and Lim (1930). *J. Agric. Chem. Soc. (Japan)* **6**, 109

Thompson, A. R. (1908). *Hawaii Stn. Report*, p. 51

—————— (1915). *J. Agric. Res.* **3**, 425

van Veen, A. G. (1932). *Zeit. Physiol. Chem.* **208**, 125

————— (1933). Cited from *Chem. Abst.* **27**, 5101

————— (1934). Cited from *Chem. Abst.* **28**, 1386, 1934

Vedder, E. B. and Feliciano, R. T. (1928). *Phil. J. Sci.* **35**, 351

Wells, A. H. (1921). *Phil. J. Sci.* **19**, 67

West, A. P. and Cruz, A. O. (1933). *Phil. J. Sci.* **52**, 1

Williams, R. R. and Saleeby, N. M. (1915). *Phil. J. Sci.* **10-B**, 99

Wise, F. B. and Broomell, A. W. (1915). *U. S. Dept. Agric. Bull.* **330**

A STUDY OF THE MICROBIOLOGICAL CONDITIONS EXISTING IN RICE SOILS

BY

PRAN KUMAR DE

AND

NRIPENDRA MOHON BOSE

Agricultural Chemistry Section, Dacca University

(Received for publication on 4th September 1937)

In view of the fact that rice is largely grown in India and that the conditions occurring in rice soils are widely different from those obtaining under normal cultivation, it is desirable to have some knowledge of the microbiological activities in these soils at different seasons of the year in order to understand the relationship of various groups of micro-organisms to their environment.

The conditions existing in the rice soils of India fall into three distinct stages, which may be described as follows :—

(*1*) *Water-logging period.*—This period extends from the time of puddling up to harvest. During this period, which usually begins by the middle of July and ends by November, the soils remain under water, the depth of which may vary from a few inches to a few feet and in some cases (as in Vikrampur in Dacca) even to a few yards.

(*2*) *Dry period.*—After harvest the soils are allowed to dry up. The conditions at this stage, particularly during winter which comes soon after harvest, remain very suitable for microbiological activity. The average temperature lies between 25° and 30° C. and the soils remain sufficiently moist to favour the growth of the micro-organisms.

(*3*) *Desiccating period.*—After winter the temperature gradually rises, and the soils lose moisture at a very rapid rate. Determinations of moisture made in this laboratory showed that even in spring the moisture contents of some soils went as low as 2 per cent on dry basis. The temperature in summer frequently goes above 50° C., when intense heat causes desiccation of the soils which sometimes become extremely hard with formation of large cracks all over the field. These conditions, which are obviously unfavourable for microbial growth, prevail till the soil is puddled for next transplantation, though occasionally, specially in late spring and in early summer when heavy rains sometimes fall, the conditions may become temporarily favourable for the growth of the micro-organisms.

Although in winter the conditions of rice soils become somewhat similar to those obtaining under dry cultivation, nevertheless, there may be marked differences in the microbiological activities in the soils under the above two conditions. In the dry cultivated soils, except the seasonal changes in moisture and temperature, the conditions remain more or less uniform so that the micro-organisms are never put to any unfavourable spells. But in rice soils, the 'dry period' follows a long period of water-logging, *i.e.*, a favourable period sets in after a long unfavourable period. Russell [1914] states that "activity of the bacteria of the soils is increased by exposing the soils to conditions unfavourable to active life and then allowing the conditions to become more favourable again. On the other hand the bacterial activity suffers in the long run when the soil is uniformly maintained in favourable conditions".

The present investigation has been undertaken to obtain some knowledge of the changes in the numbers and in activities of different groups of micro-organisms in soils under conditions similar to those occurring in rice fields, and to ascertain the extent to which the microbiological conditions of a soil, dried after a long period of water-logging, may differ from those obtaining under dry cultivation.

EXPERIMENTAL

The soil samples used in this investigation had been collected from unmanured rice fields about a year before the experiments were started, air-dried, sieved and then preserved. Since in these stored samples a large proportion of the micro-organisms was probably not present in an active state, it was decided to keep them under optimum conditions of temperature (30° C.) and moisture (15 per cent) for about a month, so as to allow sufficient time to the micro-organisms to restore their normal activities. The soils were then submitted to different treatments in order to obtain conditions corresponding to those occurring in the rice fields at different seasons of the year. The successive treatments applied to the air-dried soils were as follows :—

(1) Air-dried soils were first kept under optimum conditions of temperature and moisture for over a month.

(2) The above soils were then water-logged ; the conditions at this stage corresponded with those occurring in the rice fields during 'water-logging period'.

(3) Water-logged soils were quickly dried and again kept under optimum conditions of temperature and moisture. This stage corresponded with the 'dry period'.

(4) Lastly, the soils were occasionally kept at high temperature (50-54° C.) without adjustment of moisture, in order to obtain conditions resembling those occurring in the rice fields during 'desiccating period'.

Soils at different stages were periodically examined for (*a*) total bacteria, (*b*) total fungi, (*c*) nitrifying capacity, (*d*) *Agotobacter* numbers and (*e*) nitrogen-fixing capacity.

The data for the mechanical analyses of the soils (except Coimbatore), used in the above studies, are given in Table I.

TABLE I

Mechanical analyses of the soils

Soils	Clay per cent	Silt per cent	Fine sand per cent	Coarse sand per cent
Bhagalpur	41·4	35·5	14·7	0·4
Rajshahi	31·5	37·5	24·1	0·3
Assam	19·0	35·7	41·2	2·3
Rangpur	18·1	27·0	48·5	2·8
Karjat	16·0	25·0	41·5	6·1

VARIATIONS IN THE RELATIVE ABUNDANCE OF BACTERIA AND FUNGI

The following three soils were used in this experiment :—

Rajshahi—*p*H 8·2, Rangpur—*p*H 6·2 and Assam—*p*H 4·9.

Eight hundred gram portions of air-dried soils were distributed in large glass dishes and then treated according to the above scheme. At different stages samples were periodically withdrawn and the numbers of bacteria and fungi counted. The former was estimated by plating one-c.c. portions of a soil dilution of 1 : 250,000 on Thornton's [1922] agar and incubating the plates at 30° C. for ten days. For fungal counts a dilution of 1 : 2500 was found most suitable. One-c.c. portions of the diluted suspension were plated on Waksman's [1922] peptone-glucose agar and the plates incubated at 30° C. for three days. In both cases five parallel plates were run for each count.

The results are given in Tables II and III.

TABLE II

Variations in the relative abundance of bacteria

(*Bacteria as millions per gram of oven-dry soil*)

Soils	Water-logging period							(35) *Dry period				(64) Desiccating period		
Days	0	3	7	13	18	23	33	38	43	53	63	68	78	98
Assam .	34·3	33·1	23·7	23·5	27·4	31·0	16·2	18·6	39·2	28·6	34·4	6·1	10·7	5·8
Rajshahi .	15·2	13·5	9·1	8·6	7·8	8·4	6·0	13·0	9·0	8·7	8·3	4·5	5·6	2·9
Rangpur .	24·1	20·3	14·2	11·4	13·1	10·1	9·8	9·3	10·2	12·8	12·5	4·0	3·7	2·9

* In this and in the following tables the figures within the brackets represent the days when the conditions of the soils were changed.

TABLE III

Variations in the relative abundance of fungi
(Fungi as thousands per gram of oven-dry soil)

Soils	Water-logging period							(35) Dry period				(64) Desiccating period		
Days	0	3	7	13	18	23	33	38	43	53	63	68	78	98
Assam .	267	240	231	176	189	204	125	107	201	188	193	68	49	41
Rajshahi .	62	52	39	28	41	40	39	54	38	52	47	28	20	20
Rangpur .	298	277	320	316	216	105	116	164	106	150	127	66	38	38

The results show that the numbers of bacteria and fungi were markedly reduced after the soils were water-logged, particularly at later period of water-logging ; and although the numbers again increased in the 'dry period', the level in all cases except one (bacteria in Assam soil) was lower than that at start. In the 'desiccating period', as expected, there was considerable fall in both bacterial and fungal numbers, obviously due to the unfavourable conditions prevailing at this stage.

CHANGES IN NITRIFYING CAPACITY

An attempt was first made to count the numbers of nitrifying bacteria in the soils by the method described by Ziemiecka [1932], but this was subsequently abandoned on account of wide discrepancy between parallel counts by this method. It was then decided to determine the nitrifying capacity of the soils by observing the amount of nitrite formed after a definite incubation period in a culture solution inoculated with a definite amount of soil. Cutler and Crump [1933] have shown that the amounts of nitrite formed under above conditions are proportional to the numbers of nitrifying organisms.

Soils used in this experiment were the same as used for bacterial and fungal counts. Portions equivalent to one grm. of soil on dry basis were inoculated into duplicate flasks each containing 100 c.c. of Beesley's [1914] medium. After incubation at 30° C. for fifteen days, the flasks were removed and the nitrite formed in each was estimated by Devarda's Alloy method—the amount introduced with the inoculum being subtracted from the total amount found. There was a very good agreement between the duplicate results.

As will be seen from Table IV, the nitrifying capacity of the soils was considerably reduced during early period of water-logging, but at a later period, the values increased and in some cases even exceeded those at start. In the 'dry period', although an initial decrease was noticed in some cases, nevertheless, the values at the end were higher than those at later period of water-logging. In the 'desiccating period', the nitrifying capacity was nearly completely lost.

TABLE IV

Changes in the nitrifying capacity of the soils at different periods (Figures represent mg. of nitrite nitrogen in 100 c.c. of the medium)

Soils	Water-logging period							(33) Dry period				(62) Desiccating period		
Days	0	1	5	11	16	21	31	36	41	51	61	66	76	96
Assam .	1·7	2·1	0·3	0·3	1·2	1·0	...	1·3	1·4	1·9	2·1	0·6	0·2	0·1
Rajshahi	1·2	1·3	0·3	0·6	1·3	2·4	2·4	1·2	1·8	2·4	2·8	0·5	0·3	0·05
Rangpur .	1·3	1·3	0·8	1·1	1·7	1·9	1·8	0·8	1·4	1·9	2·4	0·4	0·3	0·05

CHANGES IN *Azotobacter* NUMBERS AND NITROGEN-FIXING CAPACITY

The following four soils were used in this experiment :—

(1) Bhagalpur	*p*H 8·4
(2) Coimbatore	*p*H 8·1
(3) Karjat	*p*H 7·8
(4) Rajshahi	*p*H 8·2

Azotobacter was counted by Winogradsky's [1926] large silica gel plate (20 cm.) method. Powdered soils* in 0·1 grm. portions (on dry basis) were evenly distributed over the surface of gels in duplicate plates by means of a fine Gooch crucible. After forty-eight hours' incubation at 30° C. the colonies were counted. For determining the nitrogen-fixing capacity, the plates were incubated for a total period of five days after which the gels were dried, care being taken to add a little dilute sulphuric acid to each plate so as to prevent the loss of ammonia by volatilisation. Nitrogen fixed in each plate was determined by Kjeldahl method and the result represented the nitrogen-fixing capacity of the soil. In most cases the duplicate figures for nitrogen-fixing capacity were much more concordant than those for *Azotobacter* counts which, in a few cases, gave highly discrepant results.

From the results which are given in Tables V and VI the following facts emerge :—

(1) On water-logging both the nitrogen-fixing capacity and the *Azotobacter* counts decreased appreciably, but after a short period they again rose almost to the original levels. This shows that it is only during the early stage of water-logging that the conditions become unfavourable for *Azotobacter* and nitrogen fixation. That this period is really unfavourable for microbial growth, was also shown by the results of bacterial and fungal counts, and of nitrifying capacity.

---

* All samples, after collection, were dried in the incubator (30° C.) for three hours, powdered and then distributed over the gels. Preliminary trials showed that no appreciable change in *Azotobacter* occurred as a result of drying the soils for this period.

(2) There was a small rise in the *Azotobacter* numbers and in nitrogen-fixing capacity during the early stage of 'dry period', but this was soon followed by a fall of the former. The nitrogen-fixing capacity, however, remained at a nearly constant level during this period.

TABLE V

Changes in the numbers of Azotobacter *colonies. Figures (mean counts in italics) represent the numbers of* Azotobacter *colonies in 0·1 grm. of soil*

Soils	Water-logging period							(60) Dry period				(93) Desiccating period		
Days	0	3	13	23	33	43	58	63	68	78	92	95	103	118
Bhagalpur	229	205	49	206	217	201	225	250	213	202	208	203	218	174
	233	215	58	195	...	235	...	216	230	190	197	...	...	...
	231	*210*	*54*	*201*	...	*218*	...	*233*	*222*	*196*	*203*	...	...	...
Coimbatore	177	209	216	218	124	208	215	198	199	127	137	126	152	100
	177	187	177	193	131	187	152	217	218	125	125	...	...	...
	177	*198*	*197*	*206*	*128*	*198*	*184*	*208*	*209*	*126*	*131*	...	...	...
Rajshahi	180	229	49	180	...	113	127	199	156	144	196	191	159	145
	171	206	38	144	...	188	150	209	168	192	188	...	...	...
	176	*218*	*44*	*162*	...	*151*	*139*	*204*	*162*	*168*	*192*	...	...	...
Karjat	34	30	32	24	21	18	16	20	27	18	24	26	30	15
	30	...	33	28	24	16	14	25	23	14	22	...	...	...
	32	...	*33*	*26*	*23*	*17*	*15*	*23*	*25*	*16*	*23*	...	...	...

TABLE VI

Changes in the nitrogen-fixing capacity of the soils (Figures represent mg. of nitrogen fixed per plate when inoculated with 0·1 grm. of soil)

Soils	Water-logging period							(60) Dry period				(93) Desiccating period		
Days	0	3	13	23	33	43	58	63	68	78	92	95	103	118
Bhagalpur	7·3	7·2	5·0	4·4	6·8	8·6	7·0	7·2	6·9	8·3	8·6	7·1	7·6	7·9
Coimbatore	6·5	5·4	6·3	4·9	5·7	7·4	6·0	6·2	7·0	8·0	6·7	7·9	7·2	7·7
Rajshahi	7·5	7·0	6·2	4·4	5·7	7·5	7·0	7·8	7·5	7·2	7·4	7·4	7·1	8·8
Karjat	3·4	3·0	4·3	3·5	4·6	4·7	1·8	3·0	3·1	4·1	3·0	3·1	2·4	...

(3) In the 'desiccating period' the nitrogen-fixing capacity remained nearly as high as in the 'dry period' although the *Azotobacter* numbers showed slight decrease. It will, however, be seen that

even after this decrease, the *Azotobacter* numbers at this stage were fairly high and much greater than those in the early stage of 'water-logging period'. *Azotobacter* thus appears to be much more resistant to high temperature and to desiccation than many of the soil organisms which, as has been seen in previous experiments, were adversely affected by the conditions prevailing at this stage.

From the above results it does not appear possible that any fixation of nitrogen will take place in the rice soils during the early period of water-logging. As regards the fixation at other periods, the results indicate that the conditions obtaining during the later stage of water-logging and in 'dry period' are favourable for the growth of *Azotobacter*, and perhaps some fixation takes place in the rice soils at these stages. But it should be remembered that the fixation of nitrogen in the soil depends on many factors, such as the supply of available phosphate, energy, etc., the absence of which may inhibit nitrogen-fixation even though the *Azotobacter* counts may be very high.

A COMPARISON OF THE MICROBIOLOGICAL CONDITIONS OCCURRING IN THE RICE SOILS AT 'DRY PERIOD' WITH THOSE EXISTING IN NORMAL AGRICULTURAL SOILS

The object of the following experiments is to find out to what extent the microbiological conditions of the rice soils in 'dry period' may differ from those occurring in normal agricultural soils. It has already been stated that the essential difference in the treatments applied to these soils is that the former is kept water-logged for a long period before they are dried, while the latter is maintained in dry conditions throughout the year. It was thought that previous water-logging of soil for a long time might have some effect on the activities of micro-organisms in the subsequent dry period.

The details of the experiments are as follows: One thousand grm. of soils were water-logged for three months with frequent changes of water. The soils were then quickly dried and kept under optimum conditions of temperature (35—36° C.) and moisture (14—16 per cent). Similar cultures were set up with air-dried soils. The microbiological activities in the above two cultures were compared by periodic determinations of (*a*) ammonia, (*b*) nitrate, (*c*) carbon dioxide evolved and (*d*) bacterial numbers.

Ammonia and nitrate were determined by Olsen's [1929] method. Carbon dioxide evolved from soil was determined by absorption in deci-normal barium hydroxide solution and back titration against oxalic acid using phenolphthalein as indicator.

The results are shown in Tables VII, VIII, IX and X.

In the following Tables the term 'dry' refers to the soils kept under optimum conditions of temperature and moisture, while the term 'water-logged and dried' means that the soils were first exposed to a long period of water-logging (three months) and then kept under optimum conditions of temperature and moisture.

TABLE VII

Amounts of ammonia in the soils at different periods (Figures represent mg. of NH_3-N in 100 grm. of dry soil)

Soil	Days					
	0	7	15	25	35	45
Dacca—						
Dry	1·05	1·05	0·9	0·74	0·6	0·76
Water-logged and dried .	3·4	4·3	3·7	3·1	2·4	0·96
Faridpur—						
Dry	1·4	1·18	1·5	0·83	0·7	1·16
Water-logged and dried .	0·87	1·03	0·87	1·18	1·16	0·77
Comilla—						
Dry	1·17	1·6	0·57	0·8	0·65	..
Water-logged and dried .	4·5	4·2	3·7	2·2	1·66	..

TABLE VIII

Amounts of nitrate in the soils at different periods (Figures represent mg. of NO_3-N in 100 grm. of soil)

Soil	Days					
	0	7	15	25	35	45
Dacca—						
Dry	0·97	1·6	2·2	2·37	3·3	4·2
Water-logged and dried .	0·84	1·3	1·65	3·13	4·7	6·0
Faridpur—						
Dry	3·8	5·3	5·24	6·6	6·1	6·9
Water-logged and dried .	1·2	2·2	2·43	2·6	3·5	4·4
Comilla—						
Dry	1·1	2·0	3·9	4·7	4·5	..
Water-logged and dried .	0·5	1·3	2·8	4·4	5·4	..

TABLE IX

Daily evolution of CO_2 from 300 grm. of soils (CO_2 as mg.)

Days		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Dacca	Dry	46·8	26·1	20·6	16·8	18·6	16·4	15·7	13·8	10·0	12·0	8·9	6·5	7·2	7·2	7·4	...	...
	Water-logged and dried	50·7	28·9	21·9	23·7	16·2	20·6	23·0	15·3	15·3	13·1	7·4	6·7	7·2	6·1	6·3	...	...
Faridpur	Dry	36·2	30·3	22·3	22·3	16·8	12·4	18·6	11·7	10·2	8·4	7·4	6·8	7·3	6·2	6·1	6·5	...
	Water-logged and dried	22·0	13·3	12·6	12·0	10·0	9·3	12·4	8·7	8·1	7·8	7·2	5·8	6·1	5·8	5·9	6·1	...
Comilla	Dry	62·6	31·4	17·7	28·1	20·8	17·3	15·8	14·4	9·8	9·1	9·6	5·6	7·8	8·7	4·5	7·4	5·6
	Water-logged and dried	17·1	17·9	8·5	18·7	15·0	12·2	11·3	10·9	7·4	6·3	4·7	3·6	5·6	3·9	3·6	3·0	2·5

TABLE X

Bacterial numbers in the soils at different periods (Bacteria as millions per gram of dry soil)

Days	0	5	10	15	20	30	40
Dacca—							
Dry	3·0	5·0	3·7	4·1	6·1	5·4	..
Water-logged and dried	6·1	6·4	6·5	6·4	3·8	6·8	4·7
Faridpur—							
Dry . . .	7·1	24·5	19·8	19·9	27·3	13·5	18·3
Water-logged and dried	11·3	18·8	15·2	11·4	29·2	14·3	11·1

The activities of ammonifying and nitrifying organisms in different cultures are best represented by the amounts of nitrogen mineralised in each during the period of experiment. This was calculated by subtracting the amount of ammonia and nitrate at start from that found at the end of the experiment. The results, calculated in this way, are shown in Table XI.

TABLE XI

Amounts of nitrogen mineralised (N in mg.)

Soil		Ammonia and nitrate N		N mineralised
		At start	After the experiment	
Dacca	Dry	2·02	4·96	2·94
	Water-logged and dried .	4·24	6·96	2·72
Faridpur	Dry	5·2	8·06	2·86
	Water-logged and dried .	2·07	5·17	3·1
Comilla	Dry	2·27	5·15	2·88
	Water-logged and dried .	5·0	7·06	2·06

The results show that nearly equal amounts of nitrogen were mineralised in both cultures. Thus, so far as the activities of ammonifying and nitrifying organisms are concerned, the microbiological conditions in the rice soils at ‘ dry period ’ do not appear to be very much different from those occurring in normal agricultural soils.

As regards the activities of other organisms the results obtained are a little anomalous. In Dacca soil, both carbon dioxide evolution and bacterial numbers were higher in ‘ water-logged and dried ’ sample, but in Faridpur soil, the case was reverse. In Comilla soil too, carbon dioxide evolved in much greater amounts from the ‘ dry ’ sample than from the ‘ water-logged and dried ’ one. It may also be noted that in Dacca soil the differences between the two treatments are not so marked as in other two soils. There is thus nothing to show that previous water-logging of a soil for a long period may have a stimulating effect on the activities of the micro-organisms, when it is subsequently dried. The evidences, on the other hand, go to show that its effect on some of the micro-organisms at least may even be depressing.

SUMMARY

The objects of this investigation were (1) to study the changes in the numbers and in activities of different groups of micro-organisms in soils under conditions similar to those occurring in the rice fields of India, and (2) to ascertain the extent to which the microbiological conditions of a soil, dried after a long period of water-logging, may differ from those obtaining under dry cultivation. (1) To obtain conditions corresponding to those occurring in the rice fields at different seasons of the year, soils were first kept water-logged (water-logging period), then quickly dried and maintained under optimum conditions of temperature and moisture (dry period), and finally kept at high temperature (50—54° C.) without adjustment of moisture (desiccating period).

Soils at different stages were periodically examined for (1) total bacteria, (2) total fungi, (3) nitrifying capacity, (4) *Azotobacter* numbers, and (5) nitrogen-fixing capacity.

Bacterial and fungal numbers.—The numbers of bacteria and fungi were markedly reduced after the soils were water-logged, particularly at later period of water-logging. They again increased in ‘ dry period ’, but the level in all cases, except one, was lower than that at start. In the ‘ desiccating period ’ there was considerable reduction in both bacterial and fungal numbers.

Nitrifying capacity.—Nitrifying capacity of the soils was considerably reduced during the early period of water-logging, but at a later period the values again increased. In the ‘ dry period ’ the values were even higher than those at later period of water-logging, but in the ‘ desiccating period ’ the soils nearly completely lost their nitrifying capacity.

Azotobacter numbers and nitrogen-fixing capacity.—Both *Azotobacter* and nitrogen-fixing capacity decreased during the early period of water-logging, but at a later period they again increased and remained nearly at a constant level till the end of the ‘ desiccating period ’. It is significant that *Azotobacter* was not much affected by the conditions prevailing at ‘ desiccating period ’.

(2) Previous water-logging of a soil for a long period was found to have no influence on the activities of ammonifying and nitrifying organisms, when it is subsequently dried ; but evidences were obtained which suggest that its effect on some of the micro-organisms of the soil may be depressing.

The authors’ thanks are due to Professor J. C. Ghosh for his interest in this work, and to the Imperial Council of Agricultural Research for maintaining the salary of one of them (P. K. D.).

REFERENCES

Beesley, R. M. (1914). *J. Chem. Soc.* **105**, 1014

Cutler, D. W. and Crump, L. (1933). *Ann. Appl. Biol.* **20**, 291

Olsen, C. (1929). *Compt. Rend. Trav. Lab. Carlsberg.* **17**, No. 15

Russell, E. J. (1914). *J. Agric. Sci.* **6**, 18

Thornton, H. G. (1922). *Ann. Appl. Biol.* **9**, 241

Waksman, S. A. (1922). *J. Bact.* **7**, 339

Winogradskey, S. (1926). *Ann. Inst. Pasteur* **40**, 455

Ziemiecka, J. (1932). *J. Agric. Sci.* **22**, 797

A.M.L

THE DISTRIBUTION, STATUS AND BIOLOGY OF CODLING MOTH (*CYDIA POMONELLA* L.) IN BALUCHISTAN WITH NOTES ON SOME OTHER INSECTS INFESTING APPLES

24 7
26 34

BY

HEM SINGH PRUTHI, M.Sc., Ph.D. (Cantab.), F. N. I.
Imperial Entomologist, New Delhi

(Received for publication on 24th February 1938)

(With Plates XIX—XXIV and two text-figures)

CONTENTS

	Page
I. Introduction	499
II. Nature of damage, life and seasonal histories of Codling moth	500
III. Distribution and status of Codling moth in different parts of Baluchistan	505
IV. *Spilonota ocellana* Schiff.	510
Nature and extent of damage	510
Distribution	511
Life and seasonal history, etc.	511
V. *Euzophera punicella* Moore	512
VI. *Cacoecia sarcostega* Meyr.	514
VII. Summary and conclusions	516
VIII. Acknowledgments	519
IX. References	519
X. Appendices I-IV	520

I. Introduction

The Codling moth, which is known to be the most serious pest of apples, pears, etc., in almost all the fruit-growing parts of the world, had not been definitely recorded from India up to 1935, when the writer reported it from Quetta district in Baluchistan [Pruthi, 1935]. At about the same time the Agricultural Officer in Baluchistan reported that the Eucosmid moth *Spilonota ocellana* Schiff. was doing damage to apples in his province in the same way as described in the case of Codling moth and was perhaps the really important pest in that area. This looked improbable as *Spilonota ocellana* Schiff., which is widely distributed in North America, chiefly attacks leaf and flower buds, and is hence called 'bud moth'. It is not known to bore into apple fruit as is done by the Codling moth larvae. In view of the notoriety of Codling moth, the Imperial Council of Agricultural Research sanctioned a small staff to assist the writer in carrying out a survey of the fruit-growing regions of Baluchistan to ascertain the distribution and status of Codling moth and to determine the exact nature of damage done by *Spilonota ocellana* to apples in that province.

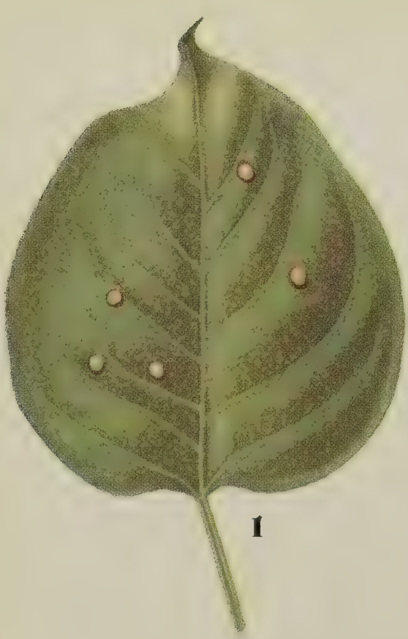
The survey was carried out during the summer (May to November) of 1937. The larvae of two more moths, *viz.*, *Euzophera punicella* Moore and *Cacoecia sarcostega* Meyr., which were sometimes seen inside apples, were also kept under observation. The main results of the investigations are reported in the following pages.

At the outset the writer visited almost all the important fruit-growing parts of Baluchistan, and, in consultation with the Agricultural Officer, selected about twenty typical localities in various regions of that province for taking detailed observations throughout the season. The various localities at which observations were to be taken were grouped together into three circles with Quetta, Fort Sandeman and Loralai as headquarters. All the three centres periodically sent samples of the fruits examined at various stations to New Delhi for close study and for the rearing of insects infesting them. Some rearing work was also done at Quetta and Fort Sandeman. All the specimens reared and collected at various stations were identified at New Delhi, where the observations taken at different localities during the season were also finally collated.

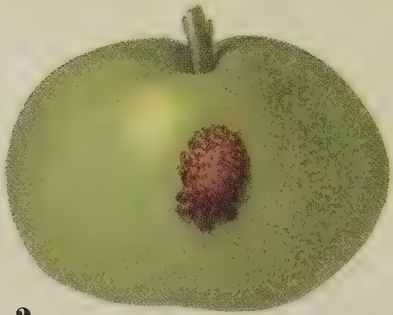
II. Nature of damage, life and seasonal histories, etc., of Codling moth

Apples, pears and quinces were observed to be the most favourite hosts of Codling moth. Peaches and plums were also found infested by this pest at Quetta but the incidence on these fruits was comparatively very low.

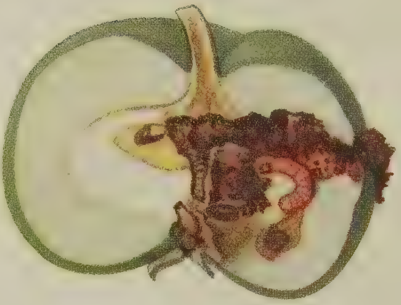
Due to the observations taken by my Assistant, Mr. C. K. Samuel, in 1932-34 and Mr. Nazeer Ahmad Janjua, Assistant Entomologist, Quetta, in 1935-36, the seasonal history of Codling moth in Baluchistan is known in broad outline. Between the middle of April and about the 10th of May, when apple and pear trees are in bloom, the moths emerge from the over-wintering larvae of the previous season. They lay eggs on leaves, twigs, flowers, etc., of the host plants. The young larva a day or so after hatching crawls on the flower when the petals are falling off, and generally enters the



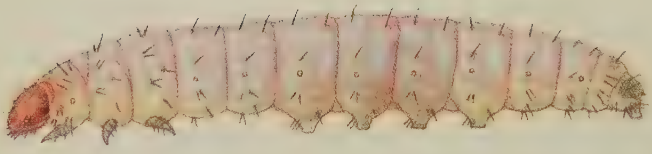
1



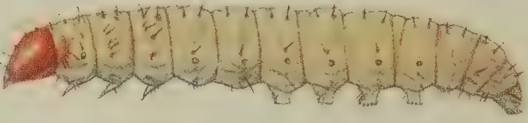
2



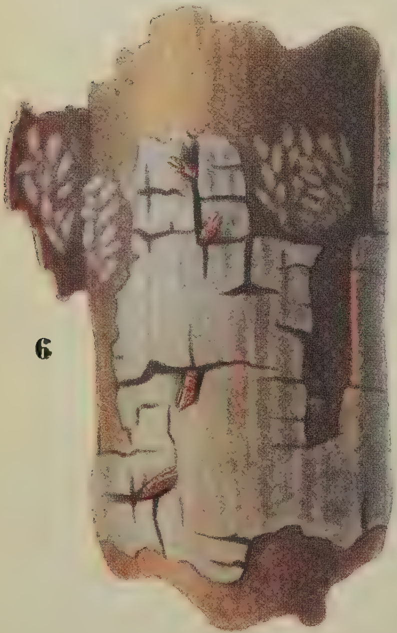
3



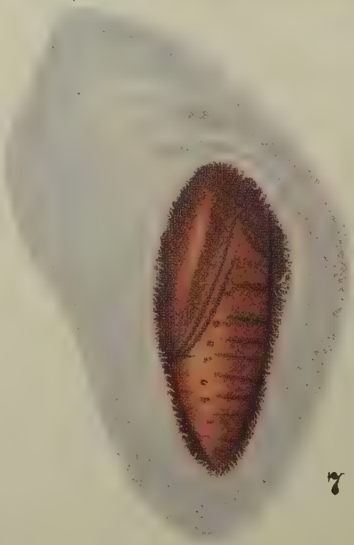
4



5



6



7

EXPLANATION OF PLATE XIX

Codling Moth, *Cydia pomonella* L.

Fig. 1. Eggs laid on a leaf. Eggs enlarged (×2)

Fig. 2. Apple fruit infested by the larva, showing the exit hole with a frass-like encrustation (nat. size)

Fig. 3. Section of damaged fruit, showing the larval tunnel with black mouldy growth. A full-grown larva near the tunnel (nat. size)

Fig. 4. The full-grown larva (×6)

Fig. 5. The full-grown larva just before pupation (×6)

Fig. 6. Batches of cocoons under bark of apple stem ($\times\frac{2}{9}$)

Fig. 7. The pupa inside a cocoon (×6)

young fruit by the calyx-end before the calyx cup gets closed. On rare occasions the fruit is entered from the stalk-end or the side. Generally one or two, sometimes three, larvae enter one fruit. On one or two occasions even five or six larvae have been found in a single fruit. The larva after its entry nibbles its way to the core of the tiny fruit, where it feeds on the young pips and the adjoining pulp. Then it starts making a transverse tunnel, which opens at the side of the fruit. It, however, keeps the opening plugged with its frass-like excreta. This opening is the exit hole by which the larva, when full grown, leaves the fruit for pupation under dry bark or any other suitable shelter. The exit hole is visible from some distance on account of the frass-like incrustation round it (Plate XIX, fig. 2). Thus a fruit damaged by Codling moth can be easily distinguished even from some distance. A small quantity of frass is also seen near the calyx-end where the young larva had entered the developing fruit (Plate XXIII, figs. 1 & 2). The larval tunnel soon becomes black due to the growth of fungi and bacteria and thus the fruit becomes entirely useless for human consumption (Plate XIX, fig. 3). The infested fruit often presents an emaciated and sometimes stunted appearance and with even moderately strong breeze falls down on the ground.

During the last summer (1937), from the fourth week of May onwards, fruits having exit holes could be seen on the trees and on the ground under them at Fort Sandeman and in the Quetta district. About the middle of June when a large number of damaged apples collected from trees as well as the ground beneath them were examined, in over fifty per cent of those from the trees the larvae had already left, whereas about seventy-five per cent of those collected from the ground were without the larvae inside. As the growth of the larvae is very much dependent on the prevailing temperature and humidity condition, the time at which the larvae leave the fruit varies at different localities. At Fort Sandeman, which is comparatively a warmer place than Quetta, the larvae started leaving the fruit about ten days earlier. Furthermore, all the larvae did not leave the fruit in a day or so, but continued to do so for about two months. The number of larvae actually found inside damaged fruits at different times of the season at various localities in the Quetta district are given in Appendix I.

After leaving the fruit the larvae select a suitable shelter under loose bark, etc., for spinning cocoons inside which they pupate (Plate XIX, figs. 6 & 7 and Plate XXIII, figs. 3, 4 & 6). Before pupation the larvae lose their pink colour and shrink in size (Plate XIX, figs. 4 & 5). The pupal period lasts about two weeks. The moths started emerging about the end of June and continued to do so up to the end of August, the maximum amount of emergence being in the first fortnight of July. These moths were naturally of the summer brood, the spring brood from the overwintering larvae having emerged in April, as described above. The moths of the summer brood lay eggs on leaves, fruits, etc., and the young larvae enter the fruits which are by now fairly well developed, near the calyx-end or the stalk-end or from the side, often selecting a place where the fruit is already injured by some physical or other agency. They enter healthy as well as infested fruit indiscriminately, but invariably avoid entering the fruit by means of the exit holes made by the old larvae.

As stated above, the period during which the larvae of the first brood left the fruit for pupation extended over two months, long enough for some larvae to become adults and give rise to the next generation while their fellows were still in the larval stage. Therefore, the larvae of both the first and second generations were found inside many fruits. This was specially the case from the middle of July up to the middle of August. It was, however, observed that the larval population of the second brood was much smaller than that of the first (Appendix I). In fig. 1 the larval populations of the two generations at different times of the season are shown graphically.

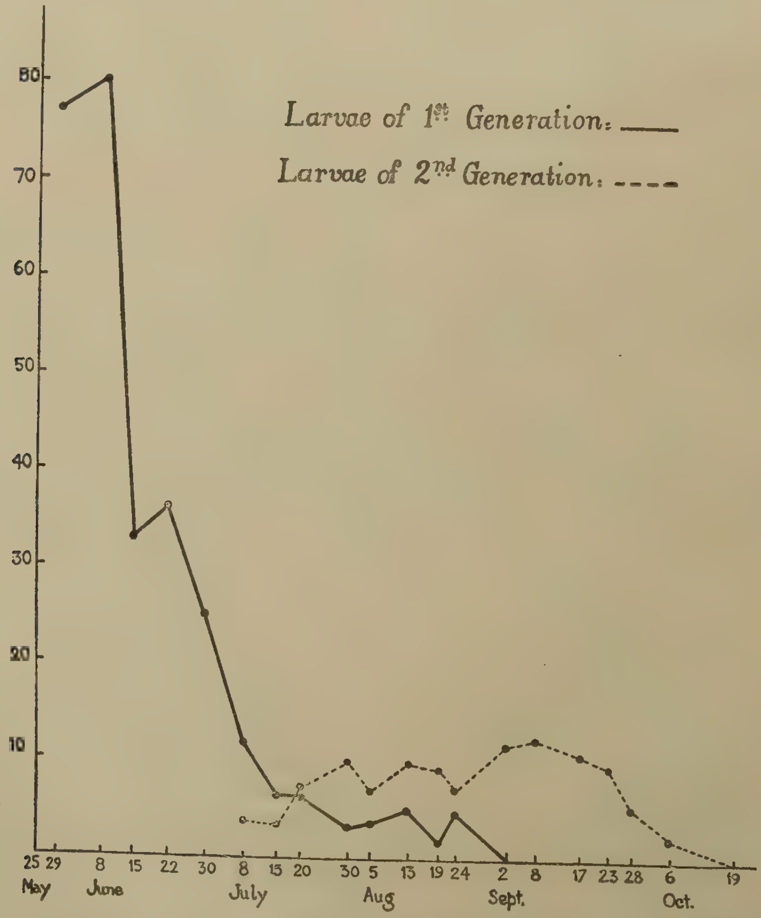


FIG. 1. Number of larvae found per 100 fruits at different times of the year

The larvae of the second brood are full grown by the end of September when they start leaving the fruit. They form cocoons, but unlike the first brood larvae they do not pupate within a few days, but pass the whole of winter in a quiescent stage. It was observed that the cocoons formed by the second brood larvae were much bigger and thicker than those made by the larvae of the first generation. In the following spring the over-wintering larvae pupate and eventually become moths and repeat the history as described above.

Life-history and description of immature stages

Some observations were taken on the life-history of Codling moth in the laboratory at New Delhi as well as at Quetta. At New Delhi rearing was done under some controlled conditions of temperature and humidity. The daily temperature and humidity observed in the Laboratory at New Delhi during July to November are given in Appendix II-A. The laboratory at Quetta was not equipped with thermometers, etc., but the record of weather conditions at the Fruit Experiment Farm where the laboratory is situated were available and are given in Appendix II-B. The detailed observations on life-history are tabulated in Appendix III, and are summarized below. Naturally the duration of various stages in the life-history was very much influenced by the prevailing temperature and humidity. However, the conclusions set forth below in reference to the influence of these factors are only tentative, as definite conclusions cannot be arrived at unless the pest has been studied under many more combinations of these factors than has so far been possible.

The moths started laying eggs soon after emergence and continued to do so till their death. The duration of their life (Appendix III-A) was about eight days at Quetta and varied from 4·3 to 12·5 days at New Delhi, depending on the conditions under which the moths were kept. It was observed at New Delhi that the life of the moth was shortened if it was kept above 75°F., and prolonged if the temperature was reduced to 68°F. The life was also shortened if the prevailing humidity was reduced from seventy-two to eighty per cent to fifty per cent. Female moths lived longer than the males and the life of both sexes was reduced by a day or so if they were given any food, *e.g.*, sugar syrup, etc.

On an average about thirty eggs were laid by a single female. One moth laid 104 eggs at New Delhi.

In the laboratory the eggs were laid freely on leaves, fruits, sides of rearing dishes, etc. The pre-oviposition period varied from two to four days at New Delhi and was about four days at Quetta (Appendix III-B).

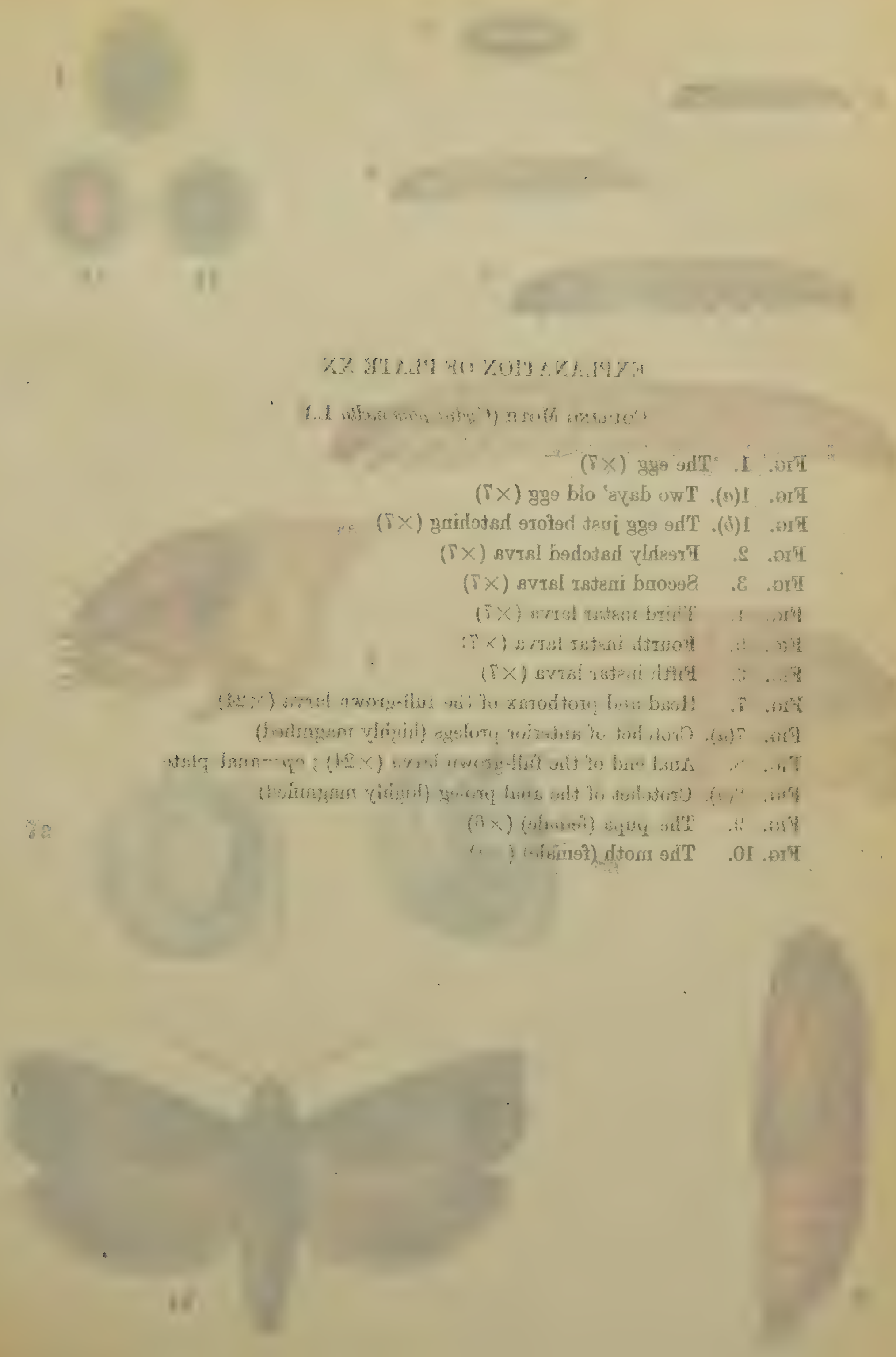
The egg (Plate XX, fig. 1) resembles an oval flat disc and is roughly the size of an ordinary stationery pin head. The average of the measurements of ten eggs is 1·12 mm. × 0·77 mm. A freshly laid egg is semi-transparent and greyish white in colour, with minute black dots all over the surface. After a few days, depending on temperature, it develops a red ring and eventually becomes opaque and shows a black spot which marks the head of the future larva (Plate XX, figs. 1*a*, 1*b*). The incubation period was about seven-and-a-half days at Quetta, whereas at New Delhi it varied from 4 to 8·5 days under various conditions (Appendix III-C).

The freshly hatched larva (Plate XX, fig. 2) is about 2 mm. in length and 0·25 mm. in breadth. The head and prothoracic shields are dark brown and the rest of the body is creamy white.

The larva undergoes four moults before it spins a cocoon. In some cases five moults were observed at New Delhi and thus there were six larval instars. The duration of various instars at Quetta and New Delhi are given in Appendix III-D.

The second instar larva (Plate XX, fig. 3) is about 4 mm. long, one day after the moult. The body of the 3rd instar larva (Plate XX, fig. 4) gradually acquires a pinkish tinge and the head becomes somewhat pale brown.

The larva becomes deep pink, especially on its dorsal side, as it grows. The last stage larva (Plate XX, fig. 6) measures 13—14·5 mm. in length and about 1·75 mm. in breadth across the first abdominal segment. The prothoracic shield becomes much lighter as the larva advances in age. The body bears short hairs arising singly. The crotchets on its prolegs are black and arranged in complete circles, except on the last pair on which they are semicircular (Plate XX, figs. 7*a* & 8*a*). The structure of the head of the full-grown larva of Codling moth has been described in detail by Lopez [1929]. It appears spherical when viewed from above. It is almost as long (1·5 mm.) as broad (Plate XX, fig. 7). There are several pairs of setae covering the surface of the head. The simple eyes consist of two groups of six pigmented ocelli each, five of which are in a semi-circle. The antennae are three segmented and the distal end of the first segment has a long hair. The labium and its palpi are prominent. The structure of the anal end of the larva is illustrated in Plate XX, fig. 8. The highly chitinized dark anal plate (*ap*) is characteristic.

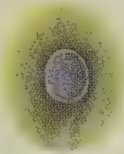


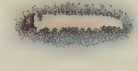
EXPLANATION OF PLATE XX

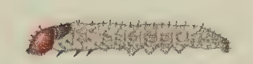
CODLING MOTH (*Cydia pomonella* L.)

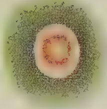
FIG. 1. The egg (×7)
FIG. 1(*a*). Two days' old egg (×7)
FIG. 1(*b*). The egg just before hatching (×7)
FIG. 2. Freshly hatched larva (×7)
FIG. 3. Second instar larva (×7)
FIG. 4. Third instar larva (×7)
FIG. 5. Fourth instar larva (×7)
FIG. 6. Fifth instar larva (×7)
FIG. 7. Head and prothorax of the full-grown larva (×24)
FIG. 7(*a*). Crotchet of anterior prolegs (highly magnified)
FIG. 8. Anal end of the full-grown larva (×24) ; *ap*=anal plate
FIG. 8(*a*). Crotchet of the anal proleg (highly magnified)
FIG. 9. The pupa (female) (×6)
FIG. 10. The moth (female) (×4)

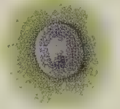
PLATE XX

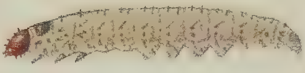

1

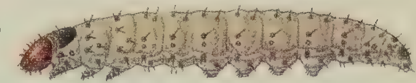

2

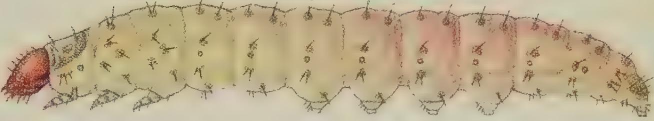

3

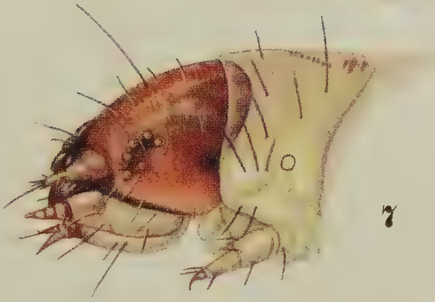

1a

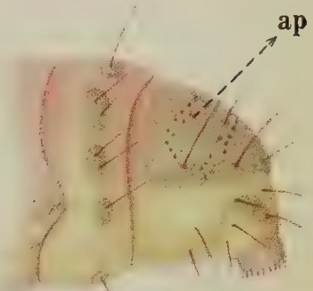

1b


4

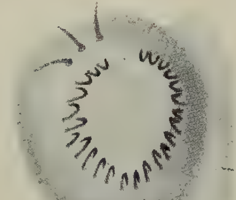

5

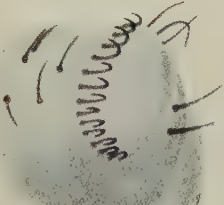

6

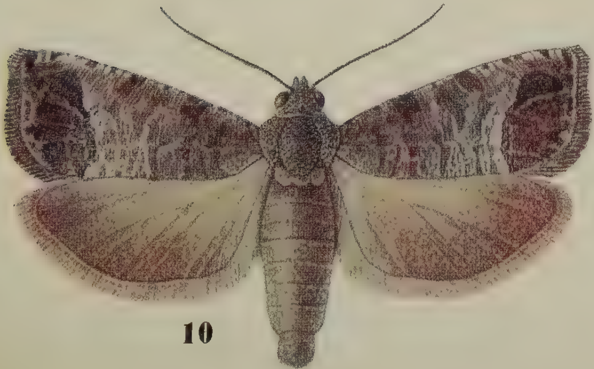

7

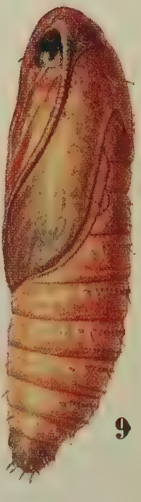


8


7a


8a


10


9

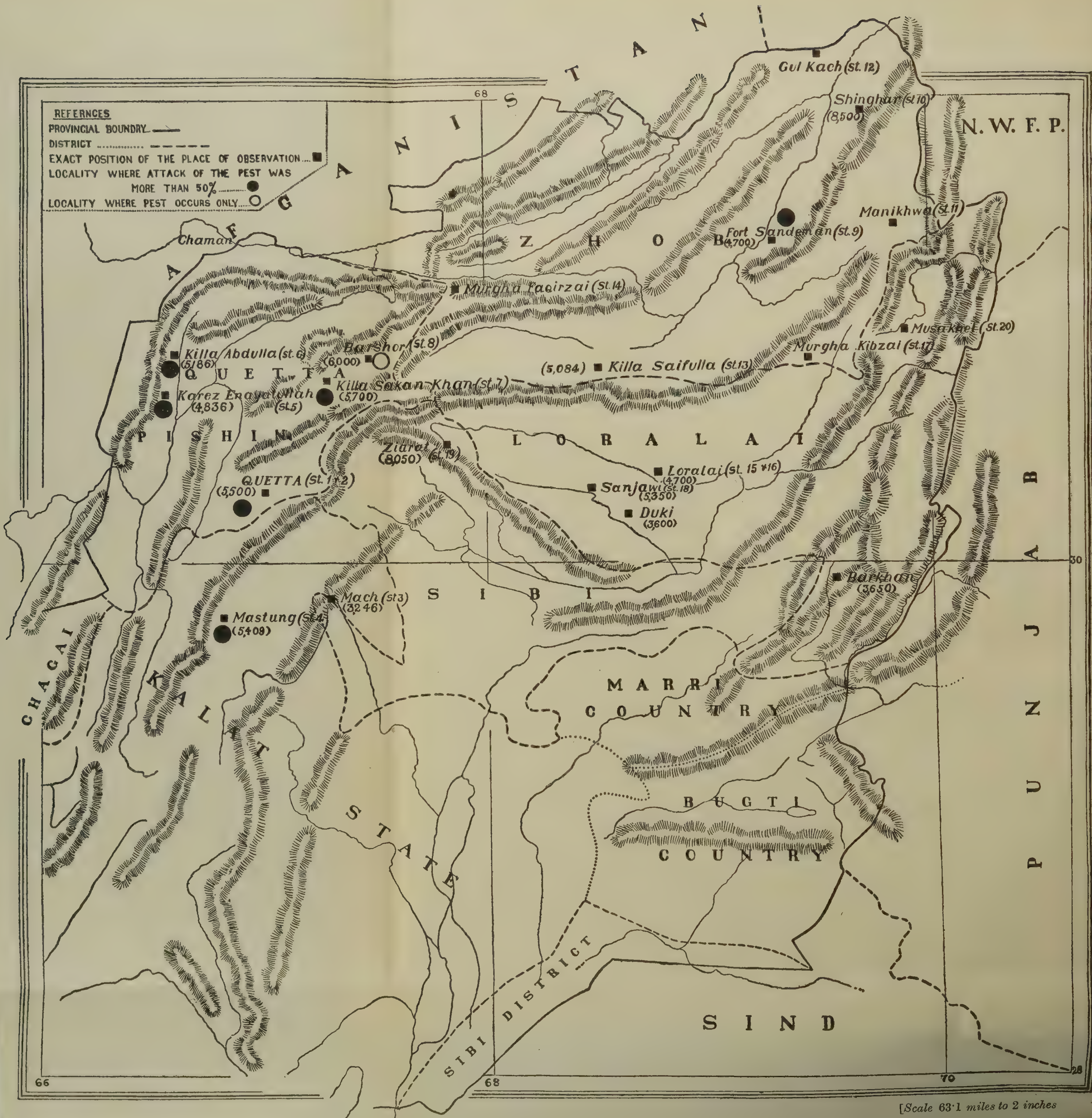

REFERNCES
PROVINCIAL BOUNDRY
DISTRICT
EXACT POSITION OF THE PLACE OF OBSERVATION ■
LOCALITY WHERE ATTACK OF THE PEST WAS MORE THAN 50% ●
LOCALITY WHERE PEST OCCURS ONLY ○
AFGANISTAN
N.W.F.P.
PUNJAB
SIND
ZHOB
LORALAI
QUETTA
PISHIN
SIBI
KALAT STATE
CHAGAI
MARRI COUNTRY
BUGTI COUNTRY
SIBI DISTRICT
Chaman
Gul Kach (st. 12)
Shinghar (st. 10) (8,500)
Manikhwa (st. 11)
Fort Sandeman (st. 9) (4,700)
Murgha Faqirzai (st. 14)
Musakhel (st. 20)
Murgha Kibzai (st. 17)
Killa Abdulla (st. 6) (5,186)
Barshor (st. 8) (6,000)
(5,084) Killa Saifulla (st. 13)
Killa Sakan Khan (st. 7) (5,700)
Karez Enayatullah (st. 5) (4,836)
Ziarat (st. 19) (8,050)
Loralai (st. 15 + 16) (4,700)
Sanjawi (st. 18) (5,350)
Duki (3,600)
QUETTA (st. 1 + 2) (5,500)
Barkhan (3,650)
Mach (st 3) (3,246)
Mastung (st. 4) (5,408)
66
68
70
30
28
[Scale 63·1 miles to 2 inches

FIG. 2. Distribution of Codling moth in Baluchistan

After the larva is full grown it stops feeding, leaves the fruit and seeks some suitable shelter under which it spins a cocoon. The loose bark and the burrows of the Quetta borer (*Aeolesthes sarta* Sol.) on the apple stem afford suitable places for cocooning. Usually the cocoons were found in groups of five to twelve, sometimes of as many as twenty and even more (Plate XIX, fig. 6).

The feeding period of the larva from the date of hatching up to that of cocooning was about thirty-five days at Quetta, whereas at New Delhi it was 32·8, 47·1 and 59 days at the room temperature, 75°F. and 68°F. respectively (Appendix III-E).

The period between the formation of cocoon and the actual pupation of the larva depends on the time of the year. In summer (June-July) pupation takes place two to three days after the formation of cocoon and the pupa emerges as moth after about ten to twelve days to give rise to second generation. The duration of pupal period under different conditions is tabulated in Appendix III-E. The larvae of second generation form cocoons in September or later. At this time they do not pupate immediately but pass the whole winter in larval stage and pupate in the following spring and eventually become moths which start the first generation of that year.

The pupa (Plate XX, fig. 9) measures about 9 mm. in length and 2·3 mm. in breadth across the 3rd abdominal segment (average of the measurements of ten specimens). When freshly formed it is pale brown, but soon turns dark brown.

The moth (female) is illustrated in Plate XX, fig. 10. Meyrick's [1927] description is reproduced below :—

> " 14-19 mm. Forewings dark fuscous, finely irrorated whitish, darker-striated; basal patch sometimes darker ; a large dark coppery-brown terminal patch hardly reaching costa, anterior edge more blackish, ocellus within this edge bright coppery-metallic. Hind wings fuscous, darker terminally ; ♂ with submedian groove from base containing hair pencil. Forewings ♂ beneath with elongate dark fuscous patch below middle of disk."

III. Distribution and status of Codling moth in different parts of Baluchistan

As already stated, about twenty typical localities in various parts of the province were selected for taking detailed observations. They are shown in the map (Fig. 2). The black squares in the map mark the localities and circles indicate the status of the pest. The localities and the frequency of observations taken at each of them are listed below :—

List of localities kept under observation

Station No.	Locality and height above sea level	Gardens under observation	Frequency of observations
		I. Quetta Circle	
1	Quetta . . . (5,500 ft.)	(*a*) Forest Reserve (Gailbreth spinney).	Weekly. 15th June to 6th Oct. 1937.
		(*b*) Arbab Shah Nawaz's garden.	Once only. On 19th Oct. 1937.
2	Quetta . . .	(*a*) Residency garden .	Weekly. 22nd June to 20th Oct. 1937.
		(*b*) Malik Jan Mohd.'s garden.	Once only. On 15th June 1937.
		(*c*) Revenue Commissioner's garden.	Weekly. 7th to 15th July 1937.
		(*d*) Patel's garden . .	Weekly. 30th July to 22nd Sept. 1937.
		(*e*) Arbab Mohd. Umer's garden.	Once only. On 27th Sept. 1937
3	Mach . . . (3,246 ft.)	The old Mach garden .	Three-weekly. 29th June to 28th July 1937.
4	Mastung . . (5,409 ft.)	(*a*) Political Agent's garden	Three-weekly } 2nd July to 26th Sept. 1937.
		(*b*) Shahi Bagh . .	Do.
5	Karez Inayat Ullah (4,836 ft.)	(*a*) Abdul Ghaffur Khan's garden.	Do. } 18th June to 15th Oct. 1937.
		(*b*) Abdul Samad Khan's garden.	Do.
		(*c*) Mohd. Yakub's garden .	Do.
6	Killa Abdullah . (5,186 ft.)	Three different gardens near the village.	Do. 20th June to 17th Oct. 1937.
7	Killa Sakan Khan . (App. 5,700 ft.)	Ghulam Mohd.'s garden .	Do. 17th June to 14th Oct. 1937
8	Barshore . . (*C*. 6,000 ft.)	Abdul Khaliq Khan's garden.	Once only. On 30th Aug. 1937.
		II. Fort Sandeman Circle	
9	Fort Sandeman . (4,700 ft.)	Political Agent's garden .	Weekly. 30th June to 15th Oct. 1937.
10	Shingarh . . (8,500 ft.)	Government garden	Once only. On 2nd Sept. 1937.
11	Manikhawa . . (*C*. 6,000 ft.)	(*a*) Rest House garden .	Fortnightly. 3rd June to 9th Aug. 1937.
		(*b*) Gulistan Khan's garden	Once only. On 12th Aug. 1937.

List of localities kept under observation—contd.

Station No.	Locality and height above sea level	Gardens under observation	Frequency of observations
		II. Fort Sandeman Circle—contd.	
12	Bulkach	..	.. ....
13	Killa Saifullah (*C.* 5,000 ft.)	Jogezai Nawab's garden	Monthly. On 24th July and 22nd Aug. 1937
14	Murgha Faqirzai	..	.. ..
		III. Loralai Circle	
15	Loralai (4,700 ft.)	Political Agent's garden	Weekly. 3rd June to 31st July 1937.
16	Loralai	Apple garden	Weekly. 3rd June to 31st July 1937.
17	Murgha Kibzai (*C.* 3,500 ft.)	(*a*) Jawahar Khan's garden	Fortnightly. 30th June to 22nd July 1937.
		(*b*) Fazal Khan's garden	Do. Do.
18	Sinjawi (5,350 ft.)	Government garden	Every ten days. 26th June to 31st July 1937.
19	Ziarat (8.050 ft.)	Government garden	Every ten days in June and July, and fortnightly in August and September.
20	Musakhel (*C.* 4,000 ft.)	Government garden	1st visit, 21st June 1937. 2nd visit 9th July 1937. This station was abandoned after 2 visits because of absence of fruits.
21	Barkhan (Hajeekot) (3,627 ft.)	Hajeekot Nawab's garden	Once only on 26th July 1937. This station was added in July.

At the time of each observation the fruits borne by a number of trees as well as those lying under them on the ground were counted. The number of those found damaged by the Codling moth larvae and showing exit holes were noted. Some of the damaged fruits were dissected and the larvae contained were kept for rearing. As some time elapses between the entry of the larvae and the appearance of the exit hole, some of the apparently healthy fruits were also dissected for the larvae, but as the work was not started till after the middle of May, almost all the infested fruits had exit holes, and the apparently sound fruits were actually so.

The method of estimating the incidence may be described in some detail. As the exit hole made on the fruit by the Codling moth larva is permanent and as the first brood (spring) of larvae, which was numerically much bigger than the second (mid-summer) brood, had already entered the fruit and made exit holes, no marked progressive increase was expected in the number of damaged fruits in a particular garden as the season progressed. The actual observations showed that this expectation was justified. Therefore the examination of a garden on two or three occasions was generally sufficient to provide a measure of the incidence. This was, however, possible only in the case of small gardens, in which a sufficient number of trees to constitute a fair sample could be examined in one or two observations. But in the case of big gardens it was not possible to examine thoroughly in one observation a sufficient number of trees to ensure adequate sampling. Such gardens were visited on several occasions. Thus by the end of the season a great majority of trees in each garden had been examined twice or thrice. Therefore the mean of the incidence calculated on different occasions adequately represented the degree of incidence of the pest in the particular garden. It may be pointed out that the percentage incidence described in the following pages is based on the number of damaged fruits which were still found on the trees. Almost ninety-eight per cent of those found on the ground had exit holes as the chief cause responsible for their falling was the Codling moth. Of course, both kinds of damaged apples (found on trees and on ground) should be taken into consideration in assessing the incidence, therefore the extent of incidence based on the former and described below was much lower than the actual one.

The data collected at the various stations on the lines mentioned above are given in Appendix IV. They may be summarised as follows :—

Apples (*Appendix IV-A*)

Quetta Circle.—The mean percentage of damaged apples found on trees at different stations during the season are given in the statement below. It will be observed that the pest was not found at station 3 (Mach), it occurred in small numbers at station 8 (Barshore) and was most severe (seventy-seven to eighty-seven per cent depending on variety) at stations 6 and 7 (Killa Abdulla and Killa Sakan Khan).

The different varieties of apple, however, were not found equally damaged. Of the two common varieties, Kulu and Kandhari, the former was more heavily attacked at all the stations. Varieties Kashmiri and Shakerseb, which were available in small numbers at some stations were also found to be as heavily damaged as the Kulu and Kandhari respectively.

Statement of mean percentage of damaged apples found on trees at different stations

Station No. and locality	Varieties of apple				Remarks
	Kulu	Kandhari	Kashmiri	Shakerseb	
1 Quetta	86	78	..	..	
2 ,,	86	75	86	74	
3 Mach	..	..	..	..	Pest not found at all
4 Mastung	81	68	61	65	
5 Karez Inayat Ullah	83	74	..	..	
6 Killa Abdulla	87	77	..	..	
7 Killa Sakan Khan	87	85	85	..	
8 Barshore	..	..	..	..	Pest was found to occur in small numbers only
9 Fort Sandeman	58	..	..	..	

Fort Sandeman Circle.—The pest was only found at Fort Sandeman (Station 9) in this circle. The mean percentage of apples found damaged was fifty-eight (Kulu variety).

Loralai Circle.—The pest was not found at any station in this circle.

Pears (*Appendix IV-B*)

As regards the incidence of Codling moth in pears, extensive observations were taken at Fort Sandeman only, as there were not many large gardens in the Quetta circle. In the latter area, the casual observations showed that this fruit was as heavily attacked as apple. The data obtained at Fort Sandeman are given under Appendix IV-B. It will be observed that the percentage of damaged pears varied from forty-four to sixty-six, the mean being about fifty-five.

Quinces (*Appendix IV-C*)

This fruit was also examined in detail at Fort Sandeman only, where they are cultivated on a large scale. Early in the season the attack on this fruit cannot be easily made out because the frass-like excreta which marks the entrance or exit hole of the larva gets mixed with the fine pubescence which covers the surface of the fruit. The observations on quinces are set forth in Appendix IV-C. It will be noted that on an average ninety per cent of the fruits were found damaged by the Codling moth larvae. This fruit suffered much more severely than even apples and pears.

IV. *Spilonota ocellana* Schiff.

Spilonota ocellana Schiff. occurs in several parts of Europe and is widely distributed in North America, where it is a pest, in the larval stage, of a variety of fruit trees such as apple, pear, quince, plum, peach, cherry, etc. Porter [1924], Frost [1927] and Gilliat [1932] have described the nature of damage done by this pest. Early in the season it attacks both leaf and flower buds, hence its popular name, the bud moth; later it eats leaves and gnaws the surface of mature fruit which consequently get scarred and disfigured.

In 1935, the writer recorded the occurrence of *Spilonota ocellana* from Baluchistan. Several other species of the genus *Spilonota* are also found in India. Larvae of tender *S. rothia* Meyr. roll together and eat holes into the tender leaves of guava (*Psidium guyava*) and *jaman* (*Eugenia jambolana*) at Pusa, Shillong, and Chapra (*Proc. 3rd Ent. Meet., Pusa*). Similarly *S. Caleata* Meyr. binds together the top leaves and shoots of *Pieris ovalifolia* in Khasi hills [Fletcher, 1933].

In view of the reported confusion of damage done by *Spilonota ocellana* with that by Codling moth, the former species was studied in some detail while determining the status and distribution of Codling moth and the results of the study are briefly reported below :—

NATURE AND EXTENT OF DAMAGE

In Baluchistan *Spilonota ocellana* larvae were observed doing damage to apples and quinces. They were also found attacking cherry leaves at Quetta, but the incidence was very low.

The over-wintering larvae, enclosed inside small hibernacula made of tightly woven silk, are generally found between the angles of twigs and in the neighbourhood of flower and leaf buds. During April, as the buds begin to swell, the larvae come out of their hibernacula, crawl over the neighbouring buds in which they bore and feed on the developing flowers and leaves. When the buds open, the larvae tie together the outer leaves in a cluster by means of silken threads and continue to feed on the more concealed parts. Later on they damage mature leaves by webbing together two or three leaves and feeding inside the cluster. Thus the infested trees present several clusters of dried-up leaves and blossoms damaged by the larvae and can be distinguished even from some distance. It may be added that somewhat similar clusters of leaves are caused by another pest, *Cacoecia sarcostega* Meyr. which will be described hereinafter.

The exact mode of feeding of the larvae of *Spilonota ocellana* may be described in detail. They always feed under cover, between two or three leaves tied together with silken threads, or between a leaf and a fruit, or between two fruits in contact with each other. A silken tube is built by the larva near the midrib or a larger vein of the leaf, inside which it lives concealed. The tube is often covered by the black frass-like excreta of the larva. Occasionally the larva comes out of the tube and feeds on the epidermis and the parenchyma tissue of the leaf which therefore eventually presents several skeletonized areas. The length of the tube increases as the larva extends its feeding ground, and measures sometimes more than an inch, but the width of the tube does not show any appreciable increase. Plate XXI, figs. 3-11 illustrate the damage caused by the larvae. Occasionally the tubes are built at some distance from the midrib and sometimes even on the dorsal surface of the leaves webbed together and the larvae feed in that neighbourhood.

The fruits are only attacked if they are touching some leaves or if two fruits are in contact with each other. In the former case the neighbouring leaf is tied to the surface of the fruit by means of silken threads and occasionally a fine web of silk is also woven in between the two. The larva builds a silken tube as usual and feeds on the tied-up leaf as well as the surface of the fruit. The injury to the latter is always shallow and the damaged surface eventually develops scars. Thus the damage to the fruit is only superficial and the larvae do not bore into the fruit in the same way as is done by the Codling moth larvae.

Spilonota ocellana was found commonly attacking different varieties of apples in all the orchards examined in the vicinity of Quetta. The Kashmiri variety was observed to be more severely attacked than others. It was difficult to assess the damage done to leaves, but ten to thirty per cent of the fruit showed injuries caused by this pest. Quinces also suffered almost to the same extent as apples.

DISTRIBUTION

At Mastung and Killa Sakan Khan (stations Nos. 4 and 7) the attack was very severe indeed. There also the Kashmiri variety suffered the most. The pest was present at Karez Inayat Ullah, Killa Abdullah and Barshore (stations Nos. 5, 6 and 8), but not in large numbers. It was not found at Mach (station No. 3).

Both the Fort Sandeman and Loralai districts appeared to be free from this pest.

LIFE AND SEASONAL HISTORY, ETC.

The eggs are generally laid singly but occasionally two or three eggs overlap. They are oval, flattened, disc-shaped, and are quite transparent when fresh. Later on they become grey. They are about 0·9 mm. long and 0·75 mm. broad. The incubation period lasted for eight to eleven days in the laboratory at Quetta.

The freshly hatched larva measures about 1 mm. in length and its head is nearly twice as broad as its body. The head and the thoracic shield are dark brown and the body bears small and fine hairs. Soon after hatching it starts nibbling the epidermis of the leaf on its underside and after doing so for an hour or so, it begins making a silken tube. The full-grown larva (Plate XXI, fig. 1) is dark brown, especially in the anterior region, and measures about 12 to 16 mm. It eventually spins a cocoon which is found concealed among the webbed-up leaves. After three days the larva transforms into pupa.

The pupa (Plate XXI, fig. 2) measures about 6·5 mm. to 8 mm. in length and about 2 mm. to 2·5 mm. across the third abdominal segment. It is brown in colour. All the abdominal segments except the first two bear two transverse rows of large and fine spines respectively, the large spines being only few in number. The last segment bears in addition four large hooked spines. A few hours before emergence of the moth the pupa thrusts out about 3/5 to 3/4 of its body from the cocoon and the crumpled leaves, and the moth comes out in due course, leaving the empty pupal case projecting as such. The pupal period lasted from nine to thirteen days in the laboratory, the average being 10·7 days for twenty-seven individuals.

The moth (Plate XXII, fig. 8) has a stout body and large wings, the expansion of the forewings being about 15 mm. The head, thorax, the proximal one third and distal one fourth of the forewings are dark gray, the middle of the forewings being prominently cream white. The hind wings and abdomen are grayish brown.

The moths are commonly seen in the day time on stems, twigs, and undersurface of leaves. If disturbed they fly only a short distance. In captivity they were found to be very active at dusk and during night and lived for one or two weeks. The pre-oviposition period was three to four days.

The seasonal history of *Spilonota ocellana* may also be described in brief outline. In the Quetta district the moths emerge during May and June, sometimes even in July. The larvae grow very slowly and continue feeding up to the end of September when they measure about 3 to 4 mm. long. As autumn sets in, they start making hibernacula inside which they are to pass the winter. The hibernacula are formed of silk exuded by the larvae and they are covered with bits of dry leaves, etc. They are much tougher than the silk tubes described above in which the larvae live during summer. The larvae lie straight inside the hibernacula and their growth is suspended. In the following spring (April) they come out of the hibernacula as described already and start feeding on the young flower and leaf buds. It is at this time that they do most damage. They rapidly increase in size and are full grown in the first half of May when they pupate and eventually emerge as moths in the end of May or June and sometimes even in July. Thus there is only one generation in the year.

V. *Euzophera punicella* Moore

It was noticed that a large number of apples infested by the Codling moth larvae had also inside them the larvae of another Phycitid moth which has not been recorded from apples so far. The new larvae were carefully reared in the insectary at New Delhi and were sent to Dr. Meyrick for identification. The moth has proved to be *Euzophera punicella* Moore which was reared for the first time at Calcutta in 1890 from pomegranates sent by Cleghorn from Baluchistan (*Ind. Mus. Notes*, Vol. II, p. 28).

EXPLANATION OF PLATE XXI

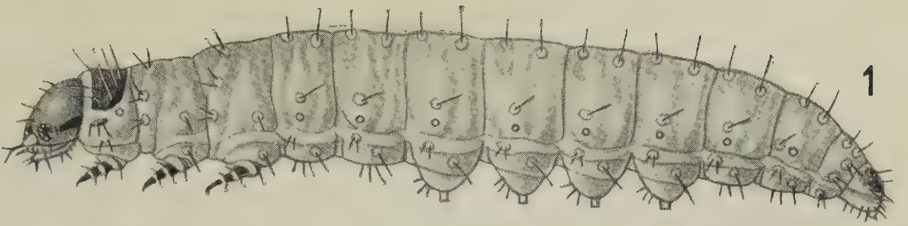
(*Spilonota ocellana* Schiff.)

Fig. 1. The full-grown larva (× 9)

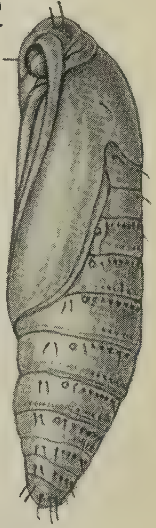
Fig. 2. The pupa (× 9)

Fig. 3-11. Leaves damaged by the larvae, showing the larval tubes, etc. In figures- 911 two leaves are webbed together (photos)

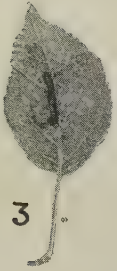
PLATE XXI



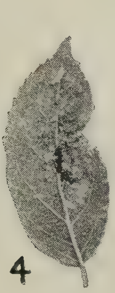
1



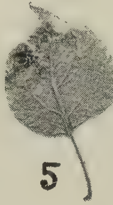
2



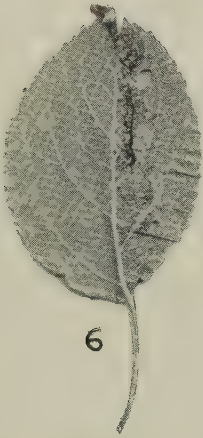
3



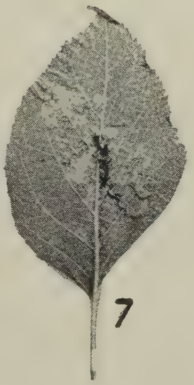
4



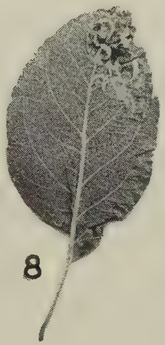
5



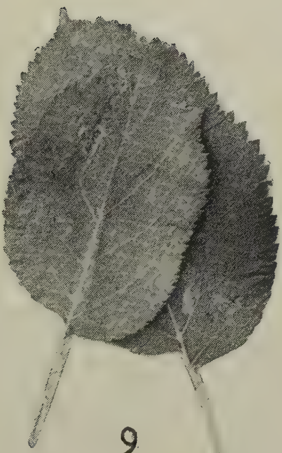
6



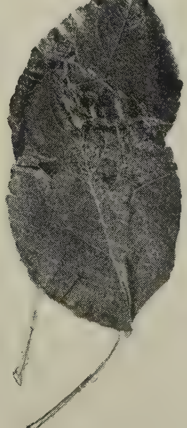
7



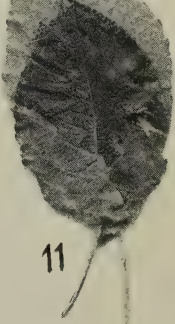
8



9



10



11

Euzophera is a big genus, of which several species are known to be stem or fruit borers. *E. perticella* Rog. is a serious pest of brinjal and damages the stem of tomato, chillies, etc., and potato tubers in several parts of India and Ceylon (*Rep. 2nd and 3rd Ent. Meet., Pusa*). *E. plumbeifasciella* Hamp. has been bred from *bael* and wood apple at Pusa and Coimbatore respectively. *E. semifuneralis* Walk. is known to bore into plum trunks in America [Hamilton, 1927] and *E. bigella* Zell. is widely distributed in Europe, Central Asia and the Far East and has been found inside apple fruits along with the Codling moth larvae and reported to be harmful to apple fruits in the same way as the latter pest [Gerasimov, 1930].

The biology of *Euzophera punicella* Moore was therefore carefully studied at New Delhi with a view to determining whether it damages apples in the same way as Codling moth. The fact, that almost invariably it was found in those apples which were also damaged by Codling moth, indicated that perhaps the *Euzophera* larvae liked the apple pulp which becomes mouldy due to the attack of the Codling moth larvae. A series of experiments were performed in which the *Euzophera* larvae were reared on healthy and infested apples and it was observed that though they were able to bore into sound fruit, they flourished best on the latter. Thus it is evident that *Euzophera punicella* is not a primary pest, but generally damages those apples which are already damaged by Codling moth.

Some notes were taken on the life-history of this species when reared in the laboratory at New Delhi, which are briefly summarized below :—

Eggs are generally laid singly or in batches of two or three. The egg measures about 0·75 mm. in length and 0·5 mm. in breadth (Plate XXII, fig. 1). It is creamy yellowish when freshly laid and its surface is rugose. The incubation period was about five days at 75° F. and seven to eight days at 68° F.

The young larva soon after hatching measures 1·5 mm. in length and 0·2 mm. in breadth. It is cylindrical in shape, gradually tapering in the posterior region. The head is pale brown, the prothoracic shield sepia brown, the rest of the body being grey (Plate XXII, fig. 2). The body is covered with numerous minute hairs arising singly.

The larva undergoes five moults before it is full grown. The full-grown larva measures 13 to 15 mm. in length and about 1·5 mm. in breadth (Plate XXII, fig. 3). The head is brown and remains retracted within the prothoracic segment. The prothoracic shield is dark grey with a crimson tinge and thus the larva though liable to be mistaken for the Codling moth larva, can be easily distinguished from the latter. The spiracles are small, circular and pale brown with dark rims. There are five pairs of prolegs including the anal claspers.

The feeding period is three to four weeks after which a thin, delicate, whitish cocoon is formed generally inside the fruit (Plate XXII, fig. 8). The pupa is elongated and measures about 7·5 mm. in length and 1·75 mm. in breadth across the 3rd abdominal segment (Plate XXII, fig. 6). Its colour is brown. The pupal period lasted about five to seven days at New Delhi.

The moths are inconspicuous and small (Plate XXII, fig. 7). The male measures about 15 mm. across the expanded forewings. Hampson's description of the female is as follows :—

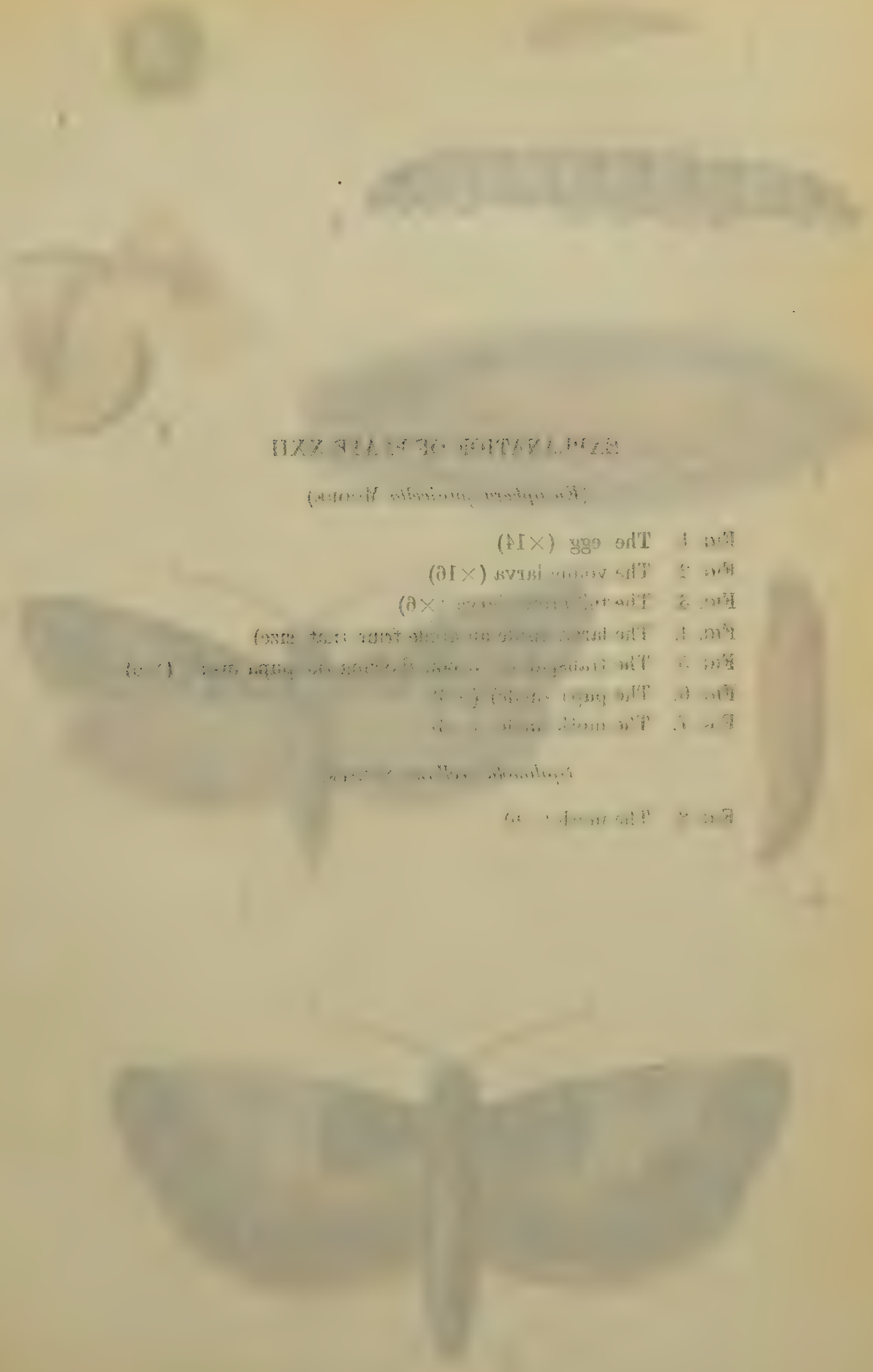
> "Fuscous, suffused with black. Forewings with diffused fuscous-black antemedial band, with whitish band on its inner edge from cell to inner margin, a post-medial line excurned from costa to vein 2. Hind wing uniform fuscous. Exp. 20 mm."

The larvae of *Euzophera punicella* were found to be heavily parasitized by a Tachinid fly and a Braconid wasp.

VI. *Cacoecia sarcostega* Meyr.

Cacoecia sarcostega Meyr. was collected for the first time in India by Fletcher at Muktesar (7,300 ft.), Kumaon hills and described by Meyrick as a new species in 1924. Other species of the genus *Cacoecia* so far recorded on apples in India are *Cacoecia pomivora* Meyr. and *Cacoecia termias* Meyr. The larvae of the former were found boring apple fruit at Ramgarh, Kumaon Hills and rolling apple and rose leaves at Shillong. The larvae of *Cacoecia termias* were found rolling apple leaves at Shillong [Fletcher, 1920, 1932]. The larvae of *C. subsidiaria* Meyr. are known to cause damage to apple leaves in Kashmir and Baluchistan.

While studying Codling moth, larvae *C. sarcostega* were sometimes noticed inside apple fruits along with the Codling moth larvae. Therefore their method of feeding and general habits were carefully observed. When a leaf is attacked by the larva of *C. sarcostega*, its petiole is severed and the leaf is tied to the surface of another leaf by means of silken threads. A sort of nest is thus formed inside which the larva lives and feeds on the soft tissue between the veins. The attacked leaves, therefore, get partially skeletonized. When a tree is severely attacked, such groups of skeletonized leaves can be seen from a distance (Plate XXIII, figs. 7 and 8). This reminds us of the attack by *Spilonota ocellana*. As regards fruit, the larva generally damages it by nibbling its skin. It ties a neighbouring leaf to the surface of the fruit and gnaws the surface of the latter under the cover of the leaf, with the result that the fruit becomes bruised and decreases in market value. Plate XXIV, fig. 4 shows the typical damage done by the larva to the fruit. When the larvae of *C. sarcostega* are found inside the fruit along with the Codling moth larvae, the fruit is entered through the exit holes of the latter, therefore, the damage by *Cacoecia sarcostega* is only of secondary importance. In several dishes containing sound fruits the larvae of this moth were introduced but no larva was successful in entering the fruit. But if apples damaged by Codling moth were provided, the larvae readily entered and started feeding on the pulp.



EXPLANATION OF PLATE XXII

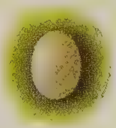
(*Euzophera punicella* MOORE)

FIG. 1. The egg (×14)
FIG. 2. The young larva (×16)
FIG. 3. The full-grown larva (×6)
FIG. 4. The larva inside an apple fruit (nat. size)
FIG. 5. The transparent cocoon showing the pupa inside (×6)
FIG. 6. The pupa (male) (×6)
FIG. 7. The moth (male) (×6)

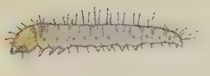
Spilonota ocellana SCHIFF.

FIG. 8. The moth (×6)

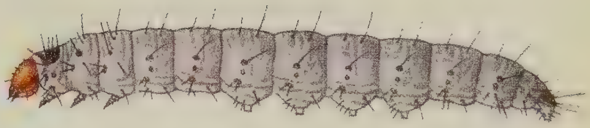
PLATE XXII



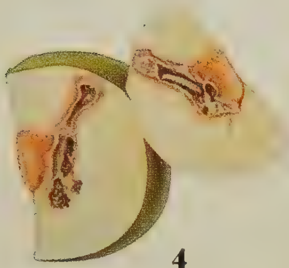
1



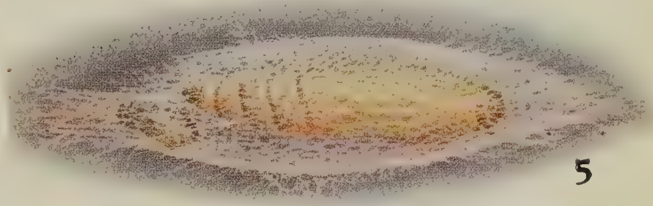
2



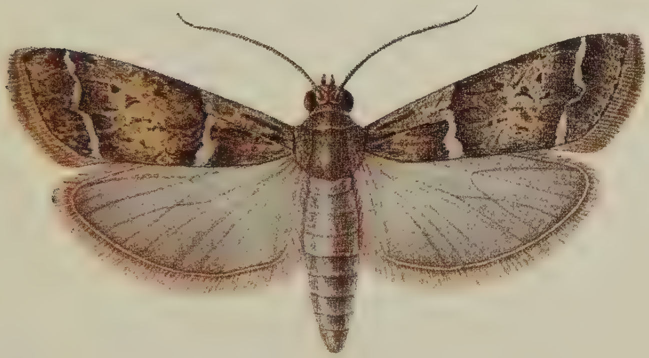
3



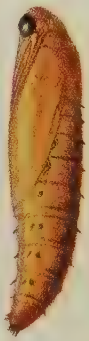
4



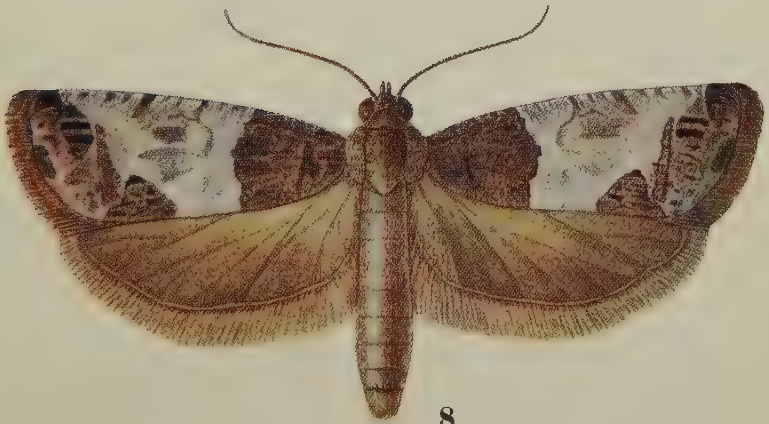
5



7

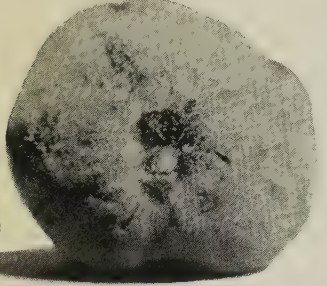


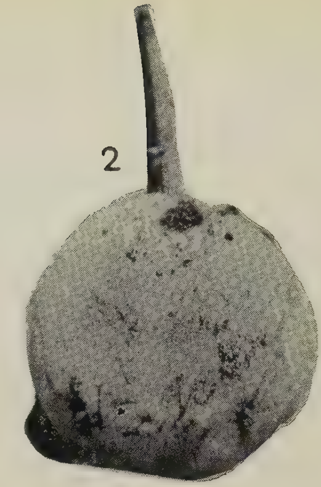
6

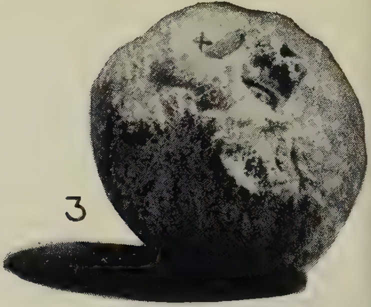


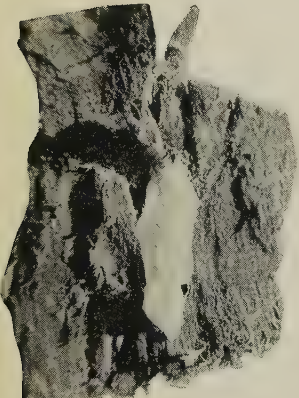
8

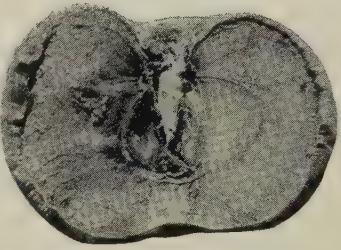
PLATE XXIII

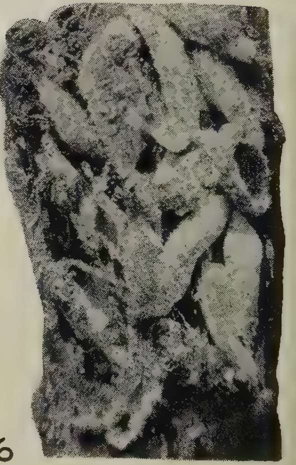

1

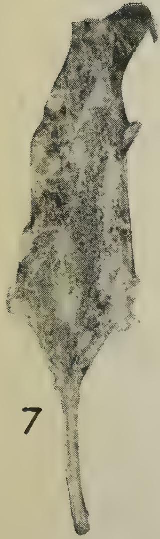

2

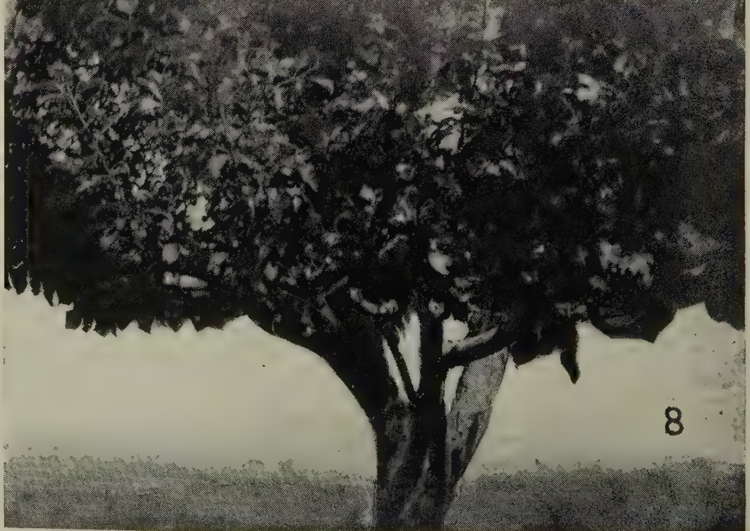

3


4


5


6


7


8

EXPLANATION OF PLATE XXIII

FIG. 1. Quince fruit showing the entrance hole of the Codling-moth larva near the calyx end

FIG. 2. Quince fruit showing the exit hole of the Codling moth larva near its stalk

FIG. 3. Pupa of Codling moth (near ×) found on the surface of the fruit

FIG. 4. Cocoon of Codling moth exposed from underneath the bark, showing the pupa coming out

FIG. 5. Apple fruit dissected showing the cocoon of *Euzophera punicella*

FIG. 6. Apple bark with numerous cocoons of Codling moth and *Euzophera punicella*

FIG. 7. Leaf damaged by *Cacoecia* larva

FIG. 8. A tree showing leaf clusters caused by *Cacoecia*

As the larvae of *Cacoecia sarcostega* thus found inside the fruit are liable to be mistaken for the Codling moth larvae, the appearance and biology of the former is briefly described below :—

The eggs are laid in a flat irregular pale green mass on the upper side of leaves. They are shingle-like and overlapping. In a mass the number of eggs varied from eighty to ninety-five. The eggs hatch out after eight to ten days.

The newly hatched larva is about 3 mm. in length and 0·5 mm. in breadth across the middle of the abdomen. The head, the thoracic shield and the first pair of thoracic legs are black and the colour of the body is pale green. After a few days the body becomes dark green (Plate XXIV, fig. 1). Almost immediately after hatching, the tiny larva moves about, nibbles here and there on leaf tissue and eventually starts constructing a small web-like shelter over itself, under the cover of which it feeds. Later on the shelter takes the form of a tube, open at both ends, under a roof-like silken web. The full-grown larva (Plate XXIV, fig. 2) is 21 mm. in length when fully extended and 2·5 mm. in breadth. It is cylindrical, gradually tapering in the distal region. The head, the prothoracic shield and the first pair of thoracic legs are of sepia brown and the colour of the body is yellowish green. The anal plate is concolorous with the body. The detailed structure of the head is shown in Plate XXIV, fig. 3.

The larva pupates inside a thin, white and elongate cocoon which it constructs between the tied-up leaves (Plate XXIV, fig. 5). The pupa measures about 10 mm. in length and 3 mm. in breadth across the wing covers on the 3rd abdominal segment (Plate XXIV, fig. 6). It is cylindrical, tapering in the posterior region. The colour is yellow brown. The 2nd to 8th abdominal segments have each a row of spines, whereas the last segment is prolonged into a strong curved brown cremaster having three hooked spines. The pupal period varied from nine to twelve days at Quetta, whereas at New Delhi it lasted from five to nine days. When the moth is about to emerge, the pupa wriggles out of the cocoon from the narrow end. The case splits open and the adult moth emerges, leaving about two-thirds of the pupal case protruding.

The moth (Plate XXIV, figs. 7 and 8) when viewed from above is bell shaped, the male being smaller than the female. The colour of the forewings is pale brown, the male having dark brown markings which are rather faint in the female. The moths are active at dusk but during the day time they are sometimes seen sitting on stems and twigs and on the upper side of the leaves of apple trees. In captivity, when fed on glucose syrup, they were found to live from about a week to ten days. When two to five days old they started laying eggs.

Cacoecia sarcostega passes through three generations during summer. The partly-grown larvae of the last brood make small hibernacula towards the end of October inside which they pass the winter. The hibernaculum is constructed of fine, soft, whitish threads, closely woven together to form a structure very similar to that formed by *Spilonota ocellana.* The larvae come out of the hibernacula during the following spring to feed on buds, blossoms and leaves and in due course become pupae and moths to repeat the life-cycle as described above.

Cacoecia sarcostega is common in almost the whole of Quetta-Pishin district, also at Fort Sandeman proper and Ziarat (station No. 19). During the summer of 1937 a very severe attack of this pest was observed on apples of Kashmiri variety at Karez Inayat Ullah (station No. 6). Besides attacking apples the larvae also damage ripe fruit of some valuable varieties of plums (mostly Santa Rosa, Alubukhara, Greengage, and Crimson Drop), apricots (*Charmagez*), peaches and nectarines, rendering them unfit for human consumption.

VII. Summary and conclusions

CODLING MOTH

About twenty typical localities in various regions of Baluchistan have been surveyed during the summer of 1937 to ascertain the distribution and status of Codling moth. The life-history of and nature of damage caused by the pest have also been studied.

The pest is found in almost whole of the Quetta-Pishin district, at Fort Sandeman in the Zhob district and at Mastung in the Kalat State. The Loralai and Sibi districts have been found to be free from the pest (fig. 2).

Excepting Barshore (Quetta district) which had the pest but, due to its inaccessibility, could not be examined more than once, at all the localities where Codling moth was found, fifty to eighty-five per cent of apple fruits were found damaged by the pest. Pears and quinces were also heavily attacked, especially at Fort Sandeman. Fruits of both old and young trees are equally attacked. Several garden owners told the writer that this pest was not evident about ten years ago and since that time was becoming more serious year after year.

The altitude of all the infested localities is between 4,500 ft. and 6,000 ft. It is noteworthy that Ziarat, which is about 8,000 ft. and is fairly close to highly infested localities [Quetta, Killa Sakan Khan (station No. 7), etc.] is free from Codling moth. It is also noteworthy that Loralai (stations Nos. 15 and 16), Killa Saif Ullah (station No. 13), Murgha Kibzai (station No. 17), Manikhowa (station No. 11), situated at about the same latitude and altitudes as some of the most highly infested localities in the Quetta district, are free from the pest.

The most remarkable case is of the Zhob district in which the pest occurs at Fort Sandeman only, where it is quite virulent, and is absent in the rest of the district, even at localities about twenty-five miles distant from Fort Sandeman, *e.g.*, Manikhowa.

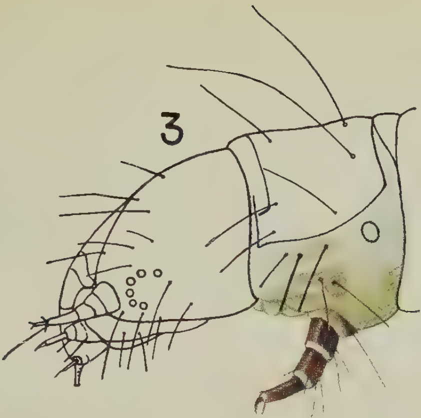
The most important difference between the Quetta (highly infested) and Loralai (entirely free) districts which strikes one is that in the former the mountain ranges are close to one another, whereas the latter area is more open. Sanjawi (station No. 18) near Loralai, which has almost the same

EXPLANATION OF PLATE XXIV

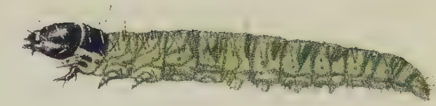
Cacoecia sarcostega Meyr.

Fig. 1. Young larva (×20)
Fig. 2. Full-grown larva (×4)
Fig. 3. The head and prothorax of the full-grown larva (×6)
Fig. 4. Apple fruit showing the typical damage done by the larvae (×$\frac{2}{3}$)
Fig. 5. The transparent cocoon showing the pupa inside (×6)
Fig. 6. The pupa (×6)
Fig. 7. The moth (male) (×4)
Fig. 8. The moth (female) (×3)

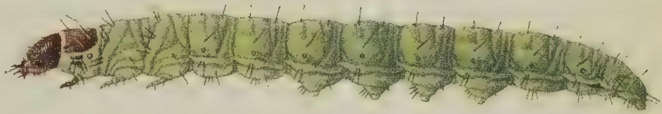
PLATE XXIV



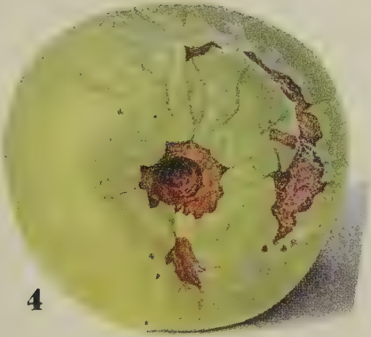
3



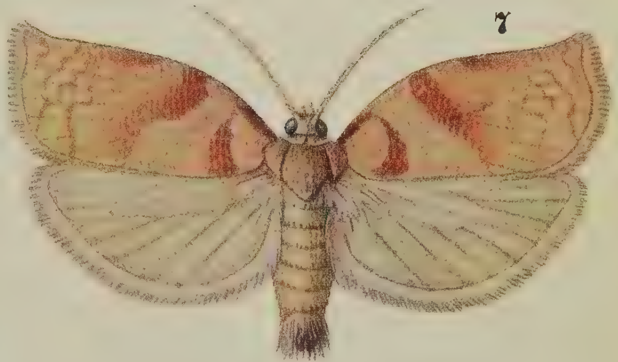
1



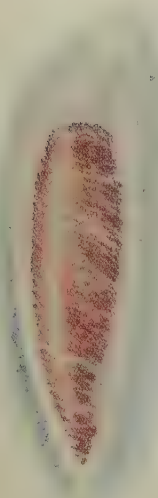
2



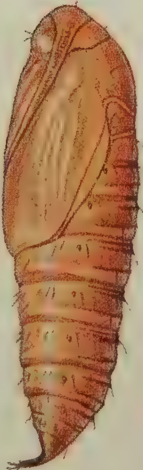
4



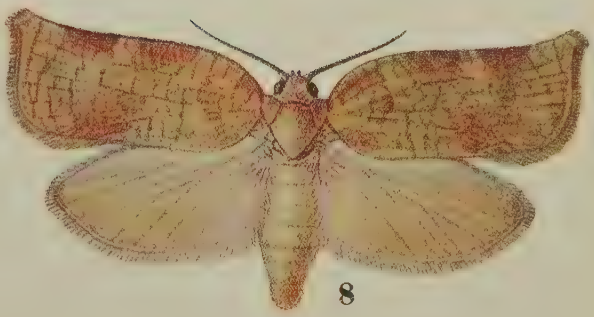
7



5



6



8

altitude as Quetta, seems to be drier and warmer than the latter. A summary of weather record during 1936 at Quetta, Fort Sandeman and Loralai is given in Appendix II-C.

From the foregoing it is evident that Codling moth flourishes best in particular areas only and these areas are determined chiefly by the temperature and humidity conditions of the environment. Study of the life-history of the pest at New Delhi under different conditions of temperature and humidity also indicates that the duration and growth of various immature stages is very much influenced by the prevailing conditions. It is not possible to define the exact conditions under which the pest flourishes best, unless the species is studied intensively under more numerous combinations of temperature and humidity than was possible during the last season due to pressure of survey work.

Introduction of Codling moth into North-West India

Codling moth definitely occurs in Baluchistan and has recently been recorded from certain parts of North-West Frontier Province [Pruthi, 1937]. It is not definitely recorded from Kashmir and is not known from Kulu or Kumaon hills or any other part of India. In view of the nature of the life-history of the pest, the most common mode of its spreading from one part to another is through the transport of infested fruit. Codling moth is known to occur in the United States of America, Europe, North and South Africa, Palestine, Australia, etc. In view of the short period in which a life-cycle is completed, it is very improbable that the pest can reach North-West India while carried inside infested apples imported by sea. In 1891 when the Railway line was extended from Quetta to Chaman, apples and other fruits began to be imported in large quantities from Afghanistan, Kandhar, etc., into Baluchistan which became the distributing centre for India. A still greater impetus was given to this trade when ice vans were introduced on that line in 1918. Though Codling moth had not been so far recorded from Afghanistan, Persia, etc., the writer suspected that it occurred at Kandhar and that it probably entered India from that area. To verify this hypothesis a few baskets of apple fruits imported from Kandhar were examined at Chaman on two occasions during September, 1937, and twenty to thirty per cent apples showed the Codling moth damage. Furthermore I understand that the Agricultural Officer in Baluchistan obtained last year some pear fruits from Mashed in Persia, some of which were found to have been damaged by Codling moth. Parachinar and other localities in the North-West Frontier Province, where Codling moth occurs, are also very close to the Afghanistan border. There is therefore enough justification for the assumption that Codling moth occurs in Afghanistan and probably was and is being introduced into India from that country.

SPILONOTA OCELLANA SCHIFF.

This species, which is known as 'bud moth' in Europe and America, occurs in large numbers in the Quetta district. Its mode of causing injury to apples has been studied in detail. During April and May the larvae feed on young leaf and flower buds and later on mature leaves. They make narrow tubes of fine silk in which they live and out of which they frequently thrust out their heads for feeding on the neighbouring leaf tissue. The tubes are generally made on the under-surface of leaves near the principal veins. They go on adding to the lengths of the tubes as their feeding grounds extend. When mature leaves are attacked, the larvae web together by silken threads two or more leaves and feed on the green parenchyma tissue between the veins and thus skeletonize the cluster. Affected trees show such clusters of skeletonized leaves even from some distance. The larva attacks the apple fruit when it is touching a leaf, in which case the leaf is webbed to the fruit and the larva feeds under the cover of the leaf, or when two fruits are in contact with each other. The larva nibbles on the surface of the fruit and therefore the injury is always shallow, resulting in a scar. It does not bore into the fruit as is done by the Codling moth larva.

The life-history of *Spilonota ocellana* has been described in some detail.

EUZOPHERA PUNICELLA MOORE

While studying the incidence of Codling moth it was observed that several fruits infested by Codling moth larvae also contained somewhat similar larvae of another moth in large numbers. The new larvae were reared at New Delhi and the moths proved to be *Euzophera punicella* Moore. The larvae of this moth were found boring pomegranates in Baluchistan in 1890. As the larvae of several other species of *Euzophera* are known to bore into a variety of fruits including apple in several parts of the world, a careful study of the mode of injury to apple fruits by *Euzophera punicella* has been made at New Delhi. It was observed that invariably the larvae of this moth were found inside those fruits only which had been damaged by Codling moth. If the larvae were put on sound fruits, they successfully bored into the fruit but did not grow so well as those fed on damaged fruit. This suggests that perhaps the moulds which grow in the tunnels made by the Codling moth larvae are liked by the larvae of *Euzophera punicella* and the exit holes made by the former afford places for an easy means of entry to the latter. *Euzophera punicella* thus does not seem to be a pest of primary importance, as it chiefly attacks those fruits only which have already been damaged by the Codling moth larvae.

The life-history of this species has been described.

CACOECIA SARCOSTEGA MEYR.

The larvae of this species are known to be pest of apple leaves. During he survey season they were sometimes found inside the fruits along with the Codling moth larvae. Their habits were therefore carefully studied. It was found that they could not bore into a sound fruit and the exit holes made by the Codling moth larvae were the only means by which they entered the fruit.

The morphology of the larva and other immature stages of *Cacoecia sarcostega* has been briefly described.

VIII. Acknowledgments

I would like to express my appreciation of the work done by the staff appointed under the Codling moth scheme, particularly Messrs. Nazir Ahmad Janjua, A. P. Kapur and V. Parbhakar Rao. Field work in Baluchistan is rather difficult and it is gratifying that these gentlemen always did the work carefully and enthusiastically. The rearing work at New Delhi was mostly under the care of my Assistants Messrs. B. Bose and C. Samuel who sometimes had to work very hard to cope with the numerous consignments of apples received from various stations in Baluchistan. I am thankful to all of them for this and to the Imperial Council of Agricultural Research, for providing funds for the scheme. I am also indebted to Mr. A. M. Mustafa, M.A., Agricultural Officer in Baluchistan, and the various district authorities in that province, who gladly co-operated with me and afforded the necessary facilities for work. Mr. Mustafa kindly gave laboratory accommodation to my staff at Quetta. But for his co-operation such a thorough survey of the pest would not have been possible.

IX. REFERENCES

Fletcher, T. B. (1920). *Mem. Dept. Agric. Ind.* (*Ent. Ser.*) **6**, 197-198

———— (1932). *Sci. Mon. Impl. Coun. Agric. Res. Ind. No.* **2**, 15 ? 21

Grasimov, A. M. (1930). *Rev. Russ. Ent.* **24**, 179-181 (Abst. *Rev. Appl. Ent. Ser. A* **19**, 1931, 595)

Hamilton, C. C. (1927). *Rep. New Jersey Agric. Expt. Stn.* 1925-26, 196-199

Headlee, T. J. (1928). *J. N. Y. Ent. Soc.* **36**, 147-63

———— (1936). *J. Econ. Ent.* **29**, 639-46

Hampson, G. F. (1896). *Faun. Brit. Ind. Moths* **4**, 73

Lopez, A. W. (1929). *Univ. Calif. Pub. Ent.* **5**, 19-36

Meyrick, E. (1924). *Exotic Micro-lepidoptera* **3**, 107-108

———— (1927). " A Revised Handbook of British Lepidoptera ", London

———— (1932). *Exotic Micro-lepidoptera* **4**, 341

Pruthi, H. S. (1935). *Agric. Live-Stock Ind.* **5**, 522-523

———— (1938). *Agric. Live-Stock Ind.* **8**, 42-43

Uspenskaya, N. (1936). *Len. Acad. Agric. Sci.* 1936, 277-80 (Abst. in *Rev. Appl. Ent. Ser. A* **25**, 1937)

Appendix I

Number and percentage of Codling moth larvae actually found inside the damaged fruits at different times of the season

Station No.	Date of collection 1937	No. of damaged apples dissected	No. of Codling moth larvae present		No. of larvae per hundred fruit	
			1st generation	2nd generation	1st generation	2nd generation
I	29th May	30	23	. .	76·6	. .
	8th—15th June	125	60	. .	48·0	. .
	22nd—30th June	201	72	. .	35·8	. .
	8th—15th July	225	22	6	9·7	2·6
	20th—30th July	212	18	18	8·9	8·9
	5th—13th Aug.	211	10	21	4·7	9·9
	19th—24th Aug.	234	7	23	2·9	9·8
	2nd—8th Sept.	125	. .	16	. .	12·8
	17th—28th Sept.	147	. .	14	. .	9·5
	6th—19th Oct.	69	. .	1	. .	1·4
II	27th May	48	62	. .	120·0	. .
	7th—15th June	73	49	. .	68·4	. .
	22nd—30th June	313	42	. .	13·4	. .
	7th—15th July	148	24	. .	16·2	. .
	20th—30th July	141	18	9	12·7	6·3
	4th—13th Aug.	95	9	18	9·4	18·8
	19th—25th Aug.	217	6	24	2·7	11·0
	1st—8th Sept.	142	3	15	2·1	10·5
	16th—27th Sept.	131	. .	10	. .	7·6
IV	2nd July	108	9	. .	8·7	. .
	30th July	141	16	12	11·3	8·5
	26th Aug.	76	3	15	3·9	6·5
	26th Sept.	59	. .	4	. .	6·7
V	18th June	216	89	. .	41·2	. .
	9th July	121	41	. .	33·8	. .
	17th Aug.	45	3	5	6·6	11·1
	19th Sept.	45	. .	5	. .	11·1
	15th Oct.	100	. .	2	. .	2·0
VI	20th June	192	47	. .	24·4	. .
	11th July	43	6	. .	13·9	. .
	19th Aug.	110	3	10	2·7	9·0
	21st Sept.	48	. .	4	. .	8·3
VII	17th June	184	52	. .	28·2	. .
	8th July	82	20	. .	24·3	. .
	16th Aug.	42	1	5	2·3	11·9
	18th Sept.	48	. .	5	. .	10·4

Appendix II-A

Temperature and humidity in the Laboratory at New Delhi from 1st July to 30th November 1937

Date	July			August			September			October			November		
	Temperature °F.			Temperature °F.			Temperature °F.			Temperature °F.			Temperature °F.		
	Maximum	Minimum	Humidity per cent	Maximum	Minimum	Humidity per cent	Maximum	Minimum	Humidity per cent	Maximum	Minimum	Humidity per cent	Maximum	Minimum	Humidity per cent
1	90	87	80	90	87	66	91	85	60	89	83	65	75	69	57
2	91	86	88	92	86	65	91	82	58	90	84	76	75	69	50
3	91	81	92	94	88	63	93	86	50	90	81	62	76	70	48
4	83	81	92	94	88	63	95	89	65	90	84	64	79	72	45
5	87	81	83	94	88	75	93	88	67	88	84	71	80	72	45
6	89	86	84	92	87	71	94	89	65	89	83	61	81	72	46
7	88	83	84	92	87	68	93	90	60	91	82	64	82	72	44
8	86	81	80	92	87	63	94	89	57	89	81	70	78	72	67
9	91	85	84	94	86	60	93	86	64	87	79	64	81	77	55
10	90	86	80	93	86	53	90	87	67	88	81	64	80	72	60
11	91	89	80	94	90	52	90	86	59	87	80	71	83	72	45
12	91	86	80	94	86	50	90	86	58	89	80	49	81	72	41
13	90	85	80	93	86	48	89	87	69	85	80	76	79	72	39
14	91	87	84	95	87	53	88	85	75	84	81	83	78	72	44
15	91	87	80	95	87	48	86	81	85	83	77	41	76	72	42
16	91	86	80	91	87	52	82	79	86	83	74	33	76	70	35
17	89	85	84	95	86	50	82	79	79	83	74	36	76	68	43
18	88	86	88	97	88	46	94	78	83	85	74	35	78	70	48
19	86	84	92	98	91	65	83	81	76	84	74	36	78	68	48
20	90	85	84	97	90	50	86	81	70	83	75	36	76	68	56
21	90	83	88	100	92	81	89	81	69	82	75	41	76	64	50
22	90	84	84	100	94	52	89	82	65	82	74	42	76	64	37
23	90	86	88	94	92	61	89	82	61	82	74	37	70	64	37
24	92	89	72	94	89	70	92	84	62	86	75	63	70	64	40
25	91	89	79	92	89	68	90	82	65	81	75	40	72	66	43
26	93	87	80	93	87	73	92	84	62	89	72	47	73	68	45
27	90	86	75	93	90	65	90	84	62	86	73	44	72	66	44
28	93	88	80	92	89	71	90	85	64	88	73	47	75	63	79
29	89	85	78	92	85	80	92	84	54	85	72	60	72	64	45
30	91	85	75	93	83	80	91	83	72	81	68	44	69	61	41
31	91	85	70	91	85	61				81	68	45			

Appendix II-B

Temperature and humidity at the Fruit Experiment Station, Quetta, during the summer of 1937

Time 1937	Average temperature °F.		Average relative humidity
	Maximum	Minimum	
1st—15th April	67·3	43·5	70·0
16th—30th April	73·8	40·6	56·4
1st—15th May	81·5	50·3	64·3
16th—31st May	87·7	56·8	55·1
1st—15th June	90·2	54·0	49·7
16th—30th June	96·0	62·4	69·0
1st—15th July	95·4	67·2	76·9
16th—31st July	93·0	66·3	77·0
1st—15th Aug.	92·7	57·6	57·3
16th—31st Aug.	93·4	57·6	71·0
1st—15th Sept.	87·9	55·0	66·8
16th—30th Sept.	82·4	41·0	35·8
1st—15th Oct.	87·5	39·6	48·0
16th—31st Oct.	70·3	34·3	62·5

Appendix II-C

Weather record during 1936 at Quetta, Fort Sandeman and Loralai

Station	January			February			March			April			May			June		
	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity
Quetta . .	45·8	23·8	89	55·6	31·0	83	59·4	34·5	72	75·2	44·4	57	89·5	54·0	55·9	94·7	62·1	62
Fort Sandeman .	52·2	29·4	67	60·8	37·5	67	64·5	41·5	61	79·5	54·6	44	96·6	70·0	39·9	98·6	73·8	54
Loralai . .	52·1	34·5	...	57·2	39·6	...	64·9	44·6	...	81·5	56·3	...	99·1	70·0	...	102·4	75·2	...

Station	July			August			September			October			November			December		
	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity	Average max. temp.	Average min. temp.	Average humidity
Quetta . .	96·2	64·9	57	93·3	56·6	49	90·9	55·5	61	81·4	37·7	40	69·9	26·5	67	50·5	30·6	86
Fort Sandeman .	98·1	74·9	63	97·6	73·3	62	92·5	68·3	65	84·2	53·7	46	70·0	39·2	38	54·2	35·7	83
Loralai .	100·2	71·5	...	96·6	72·9	...	92·6	66·4	...	82·5	54·0	...	68·3	41·6	...	55·2	38·8	...

Appendix III-A

DURATION OF LIFE OF MOTHS IN THE LABORATORY

1. At New Delhi

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
(i) Room temperature and humidity (See Appendix II)						
1	6th July 1937	13	8th July 1937	2	2	Males and females mixed ; had emerged at room temperature, were fed
			9th ,, ,,	2	3	
			10th ,, ,,	1	4	
			11th ,, ,,	3	5	
			13th ,, ,,	3	7	
			15th ,, ,,	2	9	
2	9th ,, ,,	3	14th ,, ,,	1	5	
			17th ,, ,,	1	8	
			20th ,, ,,	1	11	
3	10th ,, ,,	17	12th ,, ,,	1	2	
			14th ,, ,,	7	4	
			15th ,, ,,	1	5	
			16th ,, ,,	4	6	
			17th ,, ,,	1	7	
			18th ,, ,,	1	8	July, 1937 Maximum 11 days Minimum 1 day Average 4·7 days
			19th ,, ,,	1	9	
			20th ,, ,,	1	10	
4	13th ,, ,,	20	16th ,, ,,	13	3	
			17th ,, ,,	7	4	
5	20th ,, ,,	8	22nd ,, ,,	2	2	
			23rd ,, ,,	2	3	
			24th ,, ,,	1	4	
			28th ,, ,,	1	8	
			30th ,, ,,	2	10	
6	21st ,, ,,	2	22nd ,, ,,	1	1	
			27th ,, ,,	1	6	
7	8th ,, ,,	2	10th Aug. ,,	1	2	
			11th ,, ,,	1	3	
8	12th Aug. ,,	4	13th ,, ,,	1	1	August Maximum 5 days Minimum 1 day Average 2·8 days
			15th ,, ,,	2	3	
			17th ,, ,,	1	5	
9	9th Sept. ,,	4	12th Sept. ,,	2	3	
			15th ,, ,,	2	6	September Maximum 7 days Minimum 3 days Average 5·1 days
10	18th ,, ,,	2	24th ,, ,,	1	6	
			25th ,, ,,	1	7	

Appendix III-A—*contd.*

(ii) Room temperature (See Appendix II) and humidity 50 per cent

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
1	21st July 1937	2	23rd July 1937	1	2	Males and females mixed; had emerged at room temperature, were not fed
			25th ,, ,,	1	4	
2	30th ,, ,,	4	2nd Aug. ,,	1	3	
			4th ,, ,,	1	5	July
			5th ,, ,,	2	6	Average 3 days August
3	6th Aug. ,,	1	10th ,, ,,	1	4	Average 4·8 days

(iii) At 75° F. and humidity range from 72-80 per cent

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
1	3rd July 1937	9	5th July 1937	5	2	Males and females mixed; had emerged at room temperature, were fed
			7th ,, ,,	3	4	
			8th ,, ,,	1	5	
2	8th ,, ,,	8	10th ,, ,,	4	2	
			14th ,, ,,	1	6	
			16th ,, ,,	1	8	
			17th ,, ,,	1	9	
			20th ,, ,,	1	12	
3	9th ,, ,,	3	16th ,, ,,	2	7	
			17th ,, ,,	1	8	
4	11th ,, ,,	16	14th ,, ,,	2	3	
			16th ,, ,,	2	5	
			17th ,, ,,	5	6	
			18th ,, ,,	2	7	
			19th ,, ,,	4	8	
			21st ,, ,,	1	10	
5	15th ,, ,,	10	18th ,, ,,	1	3	
			20th ,, ,,	1	5	
			21st ,, ,,	1	6	Maximum 14 days
			22nd ,, ,,	2	7	Minimum 2 days
			23rd ,, ,,	5	8	Average 6·4 days
6	22nd ,, ,,	2	28th ,, ,,	2	6	
7	24th ,, ,,	5	26th ,, ,,	1	2	
			5th Aug. ,,	4	12	
8	26th ,, ,,	2	31st July ,,	1	5	
			3rd Aug. ,,	1	8	
9	30th ,, ,,	1	7th ,, ,,	1	8	
10	1st Sept. ,,	1	11th Sept. ,,	1	10	
11	22nd ,, ,,	3	6th Oct. ,,	3	14	

Appendix III-A—*contd.*

(iii) At 75° F. and humidity range from 72-80 per cent—contd.

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
12	17th July 1937	6	23rd July 1937	1	6	Females only; had emerged at room temperature; were not fed
			24th ,, ,,	1	7	
			25th ,, ,,	1	8	
			27th ,, ,,	1	10	
			28th ,, ,,	2	11	
13	13th Oct. ,,	1	18th Oct. ,,	1	5	
14	11th Nov. ,,	1	26th Nov. ,,	1	15	

Average .. 9·1 days

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
15	16th July ,,	8	21st July ,,	2	5	Males and females mixed; had emerged at room temperature; were not fed
			22nd ,, ,,	1	6	
			23rd ,, ,,	1	7	
			24th ,, ,,	2	8	
			26th ,, ,,	1	10	
			27th ,, ,,	1	11	

Average .. 6·5 days

(iv) At 75° F. and humidity 50 per cent

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
1	12th July 1937	9	15th Sept. 1937	2	3	Males and females mixed; had emerged at room temperature; were not fed
			16th ,, ,,	1	4	
			17th ,, ,,	1	5	
			18th ,, ,,	1	6	
			19th ,, ,,	1	7	
			20th ,, ,,	1	8	
			21st ,, ,,	1	9	
			23rd ,, ,,	1	11	
2	30th ,, ,,	1	5th Aug. ,,	1	6	
3	3rd Aug. ,,	1	6th ,, ,,	1	3	

Average 5·9 days

(v) At 75° F. and humidity range from 72-80 per cent

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
1	29th July 1937	1	7th Aug. 1937	1	9	Males only; had emerged at 75° F.; were fed
2	9th Aug. ,,	1	11th ,, ,,	1	2	
3	9th ,, ,,	1	13th ,, ,,	1	4	
4	11th ,, ,,	1	17th ,, ,,	1	6	

Appendix III-A—*contd.*

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
			(v) At 75°F. and humidity range from 72-80 per cent—contd.			
5	1st Sept. 1937	1	11th Sept. 1937	1	10	
6	7th ,, ,,	1	19th ,, ,,	1	12	
7	10th ,, ,,	1	17th ,, ,,	1	7	
				Average	7·1 days	
8	19th Aug. 1937	1	27th Aug. 1937	1	8	Males only; had emerged at 75° F.; were not fed
9	26th ,, ,,	1	29th ,, ,,	1	3	
10	28th ,, ,,	1	7th Sept. ,,	1	10	
11	28th ,, ,,	1	9th ,, ,,	1	12	
12	19th ,, ,,	1	27th Oct. ,,	1	8	
				Average	8·2 days	
13	9th Aug. 1937	1	11th Aug. 1937	1	2	Females only; had emerged at 75° F.; were fed
14	10th ,, ,,	1	23rd ,, ,,	1	13	
15	11th ,, ,,	1	25th ,, ,,	1	14	
16	7th Sept. ,,	1	28th Sept. ,,	1	21	
				Average	12·5 days	
17	7th Aug. 1937	1	19th Aug. 1937	1	12	Females only; had emerged at 75° F.; were not fed
18	15th ,, ,,	1	29th ,, ,,	1	14	
19	19th ,, ,,	1	29th ,, ,,	1	10	
20	24th ,, ,,	1	29th ,, ,,	1	5	
21	20th Sept. ,,	1	2nd Oct. ,,	1	12	
				Average	10·6 days	

Appendix III-A—*contd.*

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
(vi) At 75° F. and humidity 50 per cent						
1	29th July 1937	1	7th Aug. 1937	1	9	Male ; had emerged at 68° F. ; fed
2	31st ,, ,,	1	12th ,, ,,	1	12	Male ; had emerged at 68° F. ; not fed
3	14th Aug. ,,	1	23rd ,, ,,	1	9	Female ; had emerged at 68° F. ; fed
4	14th ,, ,,	1	24th ,, ,,	1	10	Do.
5	29th ,, ,,	1	9th Sept. ,,	1	11	Female ; had emerged at 68° F. ; fed
6	1st Sept. ,,	1	8th ,, ,,	1	7	Female ; had emerged at 68° F. ; not fed
				Average	10	days
(vii) At 68° F. and humidity range from 72-80 per cent						
1	15th Sept. 1937	1	1st Oct. 1937	1	16	Female ; had emerged at 68° F. ; fed
2	25th Oct. ,,	1	14th Nov. ,,	1	20	Female ; had emerged at 68° F ; not fed
(viii) At 68° F. and humidity range 50 per cent						
1	26th Aug. 1937	1	8th Sept. 1937	1	13	Male ; had emerged at 68° F. ; fed
2	24th ,, ,,	1	7th ,, ,,	1	14	Male ; had emerged at 68° F. ; not fed
3	9th Sept. ,,	1	17th ,, ,,	1	8	Do.
4	11th ,, ,,	1	21st ,, ,,	1	10	Male ; had emerged at 68° F. ; not fed

Appendix III-A—*concld.*

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
			(viii) At 68° F. and humidity range 50 per cent—contd.			
5	26th Aug. 1937	1	7th Sept. 1937	1	12	Female ; had emerged at 68° F. ; fed
6	20th ,, ,,	1	7th ,, ,,	1	18	Female ; had emerged at 68° F. ; not fed
			Average	12·5	days	

2. *At Quetta*

Serial No.	Date of emergence	No. of moths emerged	Date of death	No. of moths dead	Duration of life in days	Remarks
1	2nd July 1937	15	7th July 1937	1	5	Males and females mixed ; fed
			8th ,, ,,	2	6	
			9th ,, ,,	5	7	
			11th ,, ,,	4	9	
			12th ,, ,,	1	10	
			13th ,, ,,	2	11	July
2	9th ,, ,,	20	14th ,, ,,	2	5	Maximum 11 days
			16th ,, ,,	9	7	Minimum 5 days
			17th ,, ,,	6	8	Average 7·9 days
			19th ,, ,,	2	10	
			20th ,, ,,	1	11	
3	13th ,, ,,	35	19th ,, ,,	3	6	
			20th ,, ,,	8	7	
			21st ,, ,,	7	8	
			22nd ,, ,,	13	9	
			23rd ,, ,,	3	10	
			24th ,, ,,	1	11	
4	25th ,, ,,	22	31st ,, ,,	2	6	
			1st Aug. ,,	6	7	
			2nd ,, ,,	9	8	August
			3rd ,, ,,	2	9	Maximum 11 days
			4th ,, ,,	2	10	Minimum 6 days
			5th ,, ,,	1	11	Average 7·8 days
5	28th ,, ,,	20	3rd ,, ,,	3	6	
			4th ,, ,,	9	7	
			5th ,, ,,	3	8	
			6th ,, ,,	3	9	
			7th ,, ,,	2	10	

Appendix III-B

PRE-OVIPOSITION PERIOD

1. At New Delhi

Serial No.	Date of emergence of moths	No. of moths liberated	Date of oviposition	No. of eggs laid	Pre-oviposition period in days	Remarks
(i) Room temperature and humidity (See Appendix II)						
1	9th July 1937	3	15th July 1937	1	6	July
2	10th " "	17	14th " "	2	4	Maximum 6 days Minimum 2 days Average 3·2 days
3	13th " "	20	15th " "	13	2	
4	20th " "	8	22nd " "	7	2	
5	21st " "	2	23rd " "	1	2	
6	2nd Aug. "	2	3rd Aug. "	1	1	August 1 day
7	8th " "	2	9th " "		1	
8	18th Sept. "	2	21st Sept. "	12	3	September 3 days
(ii) At 75° F. and humidity range from 72-80 per cent						
1	8th July 1937	8	10th July 1937	1	2	
2	12th " "	9	15th " "	1	3	
3	15th " "	10	18th " "	10	3	
4	16th " "	10	19th " "	29	3	
5	22nd " "	2	28th " "	10	6	
6	24th " "	6	28th " "	1	4	Maximum 7 days Minimum 2 days Average 4·2 days
7	26th " "	2	30th " "	8	4	
8	30th " "	2	3rd Aug. "	4	4	
9	1st Sept. "	2	7th Sept. "	1	6	
10	7th " "	2	13th " "	1	6	
11	11th " "	5	13th " "	6	2	
12	22nd " "	3	29th " "	4	7	
(iii) At 68° F. and humidity range from 72-90 per cent						
1	16th Sept. 1937	2	20th Sept. 1937	2	4	

Appendix III-B—*contd.*

2. At Quetta

Serial No.	Date of emergence of moths	No. of moths liberated	Date of oviposition	No. of eggs laid	Pre-oviposition period in days	Remarks
1	2nd July 1937	15	5th July 1937	4	3	July
2	9th ,, ,,	20	13th ,, ,,	5	4	Maximum 5 days Minimum 3 days Average 4 days
3	13th ,, ,,	35	16th ,, ,,	7	3	
4	25th ,, ,,	22	30th ,, ,,	21	5	
5	28th ,, ,,	20	1st Aug. ,,	6	4	
6	5th Aug. ,,	9	11th ,, ,,	6	6	

Appendix III-C

INCUBATION PERIOD

1. At New Delhi

Serial No.	Oviposition		Hatching		Egg-stage in days	Remarks
	Date	No. of eggs	Date	No. of larvae		
			(i) Room temperature and humidity (See Appendix II)			
1	15th July 1937	6	18th July 1937	1	3	Eggs laid at room temperature
			19th ,, ,,	3	4	July
2	21st Sept. ,,	12	24th Sept. ,,	1	3	Average = 3·7 days
			25th ,, ,,	11	4	Moths emerged at 68° F.
3	22nd ,, ,,	22	26th ,, ,,	22	4	September Average=4 days
4	24th ,, ,,	7	28th ,, ,,	7	4	
			(ii) At 75° F. and humidity range from 72-80 per cent			
1	15th July 1937	1	18th July 1937	1	3	Eggs laid at room temperature
2	15th ,, ,,	7	18th ,, ,,	2	3	Ditto
			19th ,, ,,	1	4	
3	3rd Aug. ,,	4	9th Aug. ,,	1	6	Eggs laid at 75° F.
4	15th Sept. ,,	3	20th Sept. ,,	1	5	Ditto
5	21st ,, ,,	2	27th ,, ,,	1	6	Ditto
6	22nd ,, ,,	16	29th ,, ,,	2	7	Ditto
			30th ,, ,,	1	8	
7	23rd ,, ,,	4	29th ,, ,,	1	6	Ditto
8	29th ,, ,,	4	5th Oct. ,,	1	6	Ditto
9	22nd ,, ,,	28	28th Sept. ,,	15	6	Eggs laid at room temp. by moths emerged at 68° F.
			29th ,, ,,	13	7	
10	23rd ,, ,,	9	29th ,, ,,	9	6	Ditto
				Average	6·1	
			(iii) At 68° F. and humidity range from 72-80 per cent			
1	24th Sept. 1937	13	2nd Oct. 1937	7	8	Eggs laid at room temp. by moths emerged at 68° F.
			3rd ,, ,,	6	9	
				Average	8·46	

Appendix III-C—*contd.*

2. *At Quetta*

Serial No.	Oviposition		Hatching		Egg-stage in days	Remarks
	Date	No. of eggs	Date	No. of larvae		
1	7th July 1937	9	13th July 1937 14th ,, ,,	2 4	6 7	
2	8th ,, ,,	8	15th ,, ,,	1	7	
3	14th ,, ,,	33	21st ,, ,, 22nd ,, ,,	26 3	7 8	
4	15th ,, ,,	16	22nd ,, ,, 23rd ,, ,,	11 2	7 8	
5	17th ,, ,,	7	24th ,, ,,	3	7	
6	18th ,, ,,	12	24th ,, ,, 25th ,, ,, 26th ,, ,,	1 7 1	6 7 8	July Maximum 8 days Minimum 6 days Average 7·9 days
7	19th ,, ,,	35	26th ,, ,, 27th ,, ,,	21 5	7 8	
8	20th ,, ,,	11	27th ,, ,, 28th ,, ,,	8 1	7 8	
9	30th ,, ,,	21	5th Aug. ,, 6th ,, ,, 7th ,, ,,	11 4 2	6 7 8	August Maximum 9 days Minimum 6 days Average 7 days
10	31st ,, ,,	11	6th ,, ,, 7th ,, ,,	7 1	6 7	
11	1st Aug. ,,	20	8th ,, ,, 9th ,, ,, 10th ,, ,,	10 4 1	7 8 9	
12	2nd ,, ,,	22	9th ,, ,, 10th ,, ,, 11th ,, ,,	13 4 1	7 8 9	
13	3rd ,, ,,	12	10th ,, ,, 11th ,, ,,	7 1	7 8	

Appendix III-D

LARVAL INSTARS AND TOTAL FEEDING PERIOD

1. At Delhi

Serial No. of observations	Larval Instars													Total feeding period in days	No. of larvae
	I			II		III		IV		V		VI			
	Date of hatching	Date of moulting	Period in days	Date of moulting	Period in days	Date of moulting	Period in days	Date of moulting	Period in days	Date of moulting	Period in days	Date of cocooning	Period in days		
(i) Room temperature and humidity (See Appendix II)															
1	19th July 1937	23rd July .	4	29th July .	6	2nd Aug..	4	8th Aug.	6	...	...	23rd Aug.	15	35	1
2	24th Sept. 1937	28th Sept..	4	1st Oct. .	3	6th Oct. .	5	12th Oct. .	6	18th Oct. .	6	1st Nov..	14	38	1
3	25th Sept. 1937	29th ,, .	4	4th ,, .	5	9th ,, .	5	15th ,, .	6	25th ,, .	10	10th ,, .	16	46	1
4	18th July 1937	...	...	...	...	...	...	...	...	...	...	15th Aug. .	...	28	1
5	19th July 1937	...	...	...	...	...	...	...	...	...	...	18th ,, .	...	30	1
6	19th July 1937	...	...	...	...	...	...	...	...	...	...	23rd ,, .	...	35	1
7	28th Sept. 1937	...	...	...	...	...	...	...	...	...	...	19th Oct. .	...	21	2
8	28th Sept. 1937	...	...	...	...	...	...	...	...	...	...	4th Nov..	...	37	2

Average=32·8 days

(ii) At 75°F. and humidity range 72—80 per cent

1	18th July 1937	21st July .	3	29th July .	8	7th Aug.	9	14th Aug.	7	...	...	24th Sept. .	41	68	1
2	28th Sept. 1937	6th Oct. .	8	12th Oct. .	6	19th Oct. .	7	28th Oct. .	9	5th Nov.	8	3rd Dec. .	28	66	1
3	29th Sept. 1937	6th ,, .	7	12th ,, .	6	19th ,, .	7	29th ,, .	10	6th ,, .	8	15th ,, .	39	77	1
4	18th July 1937	...	...	...	...	...	...	...	...	...	...	23rd Aug.	...	36	1
5	19th July 1937	...	...	...	...	...	...	...	...	...	...	14th ,, .	...	26	1
6	29th Sept. 1937	...	...	...	...	...	...	...	...	...	...	25th Oct. .	...	26	1
7	29th Sept. 1937	...	...	...	...	...	...	...	...	...	...	30th ,, .	...	31	1

Average 47·1 days

(iii) At 68°F. and humidity range 72—80 per cent

1	3rd Oct. 1937	12th Oct. .	9	19th Oct. .	7	29th Oct . .	10	6th Nov. .	8	15th Nov.	9	29th Nov.	14	57	1
2	3rd ,, . 1937	13th ,, .	10	20th ,, .	7	28th ,, .	8	6th ,, .	9	19th ,, .	13	3rd Dec. .	14	61	1

Average 59 days

2. At Quetta

1	21st July 1937	25th July .	4	29th July .	4	4th Aug.	6	17th Aug.	13	...	...	28th Aug.	11	38	1
2	21st July 1937	26th ,, .	5	29th ,, .	3	4th ,, .	6	15th ,, .	11	...	...	25th ,, .	10	35	1
3	21st July 1937	26th ,, .	5	30th ,, .	4	6th ,, .	7	18th ,, .	12	...	...	30th ,, .	12	40	1
4	22nd July 1937	26th ,, .	4	30th ,, .	4	5th ,, .	6	14th ,, .	9	...	...	24th ,, .	10	33	1
5	22nd July 1937	28th ,, .	6	31st ,, .	3	6th ,, .	6	16th ,, .	10	...	...	27th ,, .	11	36	1
6	26th July 1937	31st ,, .	5	4th Aug.	4	11th ,, .	7	22nd ,, .	11	...	...	4th Sept. .	13	40	1

Appendix III-D—*contd.*

Serial No. of observations	Larval instars													Total feeding period in days	No. of larvae
	I			II		III		IV		V		VI			
	Date of hatching	Date of moulting	Period in days	Date of moulting	Period in days	Date of moulting	Period in days	Date of moulting	Period in days	Date of moulting	Period in days	Date of cocooning	Period in days		
	2. At Quetta—contd.														
7	26th July 1937	31st July	5	4th Aug.	4	12th Aug.	8	27th Aug.	15	...	...	9th Sept.	13	45	1
8	6th Aug. 1937	11th Aug.	5	16th ,,	5	22nd ,,	6	1st Sept.	10	...	...	11th ,,	10	36	1
9	9th Aug. 1937	13th ,,	4	17th ,,	4	23rd ,,	6	2nd ,,	10	...	...	13th ,,	11	35	1
10	9th Aug. 1937	13th ,,	4	17th ,,	4	24th ,,	7	7th ,,	14	...	...	20th ,,	13	42	1
11	9th Aug. 1937	14th ,,	5	19th ,,	5	26th ,,	7	8th ,,	13	...	...	20th ,,	12	42	1
12	10th Aug. 1937	15th ,,	5	20th ,,	5	26th ,,	6	7th ,,	12	...	...	17th ,,	10	38	1
13	10th Aug. 1937	16th ,,	6	21st ,,	5	29th ,,	8	9th ,,	11	...	...	23rd ,,	14	44	1
14	14th July 1937	...	...	...	...	...	...	...	...	...	...	19th Aug.	...	36	1
15	14th July 1937	...	...	...	...	...	...	...	...	...	...	21st ,,	...	38	1
16	21st July 1937	...	...	...	...	...	...	...	...	...	...	24th ,,	...	34	4
17	21st July 1937	...	...	...	...	...	...	...	...	...	...	27th ,,	...	37	3
18	22nd July 1937	...	...	...	...	...	...	...	...	...	...	23rd ,,	...	32	1
19	22nd July 1937	...	...	...	...	...	...	...	...	...	...	24th ,,	...	33	1
20	24th July 1937	...	...	...	...	...	...	...	...	...	...	29th ,,	...	36	1

21	24th July 1937	...	...	...	...	...	...	...	...	...	...	30th Aug. .	...	37	1
22	25th July 1937	...	...	...	...	...	...	...	...	...	...	25th ,, .	...	31	1
23	25th July 1937	...	...	...	...	...	...	...	...	...	...	28th ,, .	...	34	2
24	26th July 1937	...	...	...	...	...	...	...	...	...	...	25th ,, .	...	30	2
25	26th July 1937	...	...	...	...	...	...	...	...	...	...	27th ,, .	...	32	4
26	26th July 1937	...	...	...	...	...	...	...	...	...	...	28th ,, .	...	33	5
27	26th July 1937	...	...	...	...	...	...	...	...	...	...	31st ,, .	...	36	1
28	26th July 1937	...	...	...	...	...	...	...	...	...	...	9th Sept. .	...	45	1
29	5th Aug. 1937	...	...	...	...	...	...	...	...	...	...	4th ,, .	...	30	1
30	5th Aug. 1937	...	...	...	...	...	...	...	...	...	...	8th ,, .	...	34	2
31	6th Aug. 1937	...	...	...	...	...	...	...	...	...	...	6th ,, .	...	31	2
32	6th Aug. 1937	...	...	...	...	...	...	...	...	...	...	10th ,, .	...	35	2
33	8th Aug. 1937	...	...	...	...	...	...	...	...	...	...	13th ,, .	...	36	2
34	9th Aug. 1937	...	...	...	...	...	...	...	...	...	...	13th ,, .	...	35	2
35	9th Aug. 1937	...	...	...	...	...	...	...	...	...	...	15th ,, .	...	37	1
36	9th Aug. 1937	...	...	...	...	...	...	...	...	...	...	20th ,, .	...	42	1
37	10th Aug. 1937	...	...	...	...	...	...	...	...	...	...	17th ,, .	...	38	1
38	10th Aug. 1937	...	...	...	...	...	...	...	...	...	...	20th ,, .	...	41	1
													Average	35	days

Appendix III-E

DURATION OF PUPAL PERIOD

1. At New Delhi

Serial No.	Date of pupation	Date of emergence	Pupal period in days	No. of individuals under observation	Remarks
(i) Room temperature and humidity (See Appendix II)					
1	26th June 1937	4th July 1937	8	1	
2	29th ,, ,,	5th ,, ,,	6	1	
3	2nd July ,,	7th ,, ,,	5	1	July
4	6th ,, ,,	13th ,, ,,	7	1	Maximum 11 days
5	7th ,, ,,	14th ,, ,,	7	1	Minimum 5 days
6	8th ,, ,,	17th ,, ,,	9	1	Average 8 days
7	9th ,, ,,	20th ,, ,,	11	1	
8	13th ,, ,,	22nd ,, ,,	9	1	
9	17th ,, ,,	26th ,, ,,	9	1	
10	22nd ,, ,,	31st ,, ,,	9	1	
11	26th ,, ,,	4th Aug. ,,	9	1	August
12	30th ,, ,,	8th ,, ,,	9	1	Maximum 9 days
13	1st Aug. ,,	9th ,, ,,	8	1	Minimum 7 days
14	3rd ,, ,,	12th ,, ,,	9	1	Average 8·4 days
15	6th ,, ,,	13th ,, ,,	7	1	
16	23rd ,, ,,	1st Sept. ,,	9	1	September
17	28th ,, ,,	5th ,, ,,	8	1	Maximum 9 days
18	30th ,, ,,	8th ,, ,,	9	1	Minimum 7 days
19	2nd Sept. ,,	9th ,, ,,	7	1	Average 8·2 days
20	2nd ,, ,,	10th ,, ,,	8	1	
21	2nd ,, ,,	11th ,, ,,	9	1	

Appendix III-E—*contd.*

Serial No.	Date of pupation	Date of emergence	Pupal period in days	No. of individuals under observation	Remarks
(i) Room temperature and humidity (See Appendix II)—contd.					
22	4th Sept. 1937	12th Sept. 1937	8	1	
23	4th ,, ,,	13th ,, ,,	9	1	
24	22nd ,, ,,	29th ,, ,,	7	1	
25	13th Oct. ,,	24th Oct. ,,	11	1	
(ii) At 75° F. and humidity range 72-80 per cent					
1	19th July 1937	29th July 1937	10	1	
2	28th ,, ,,	7th Aug. ,,	10	1	
3	28th ,, ,,	10th ,, ,,	13	1	
4	29th ,, ,,	9th ,, ,,	11	2	
5	30th ,, ,,	9th ,, ,,	10	2	
6	30th ,, ,,	10th ,, ,,	11	1	
7	1st Aug. ,,	11th ,, ,,	10	2	
8	6th ,, ,,	15th ,, ,,	9	1	Maximum 13 days
9	9th ,, ,,	19th ,, ,,	10	2	Minimum 7 days
10	17th ,, ,,	24th ,, ,,	7	1	Average 10·1 days
11	17th ,, ,,	26th ,, ,,	9	1	
12	17th ,, ,,	28th ,, ,,	11	1	
13	18th ,, ,,	28th ,, ,,	10	1	
14	22nd ,, ,,	1st Oct. ,,	10	1	
15	27th ,, ,,	7th ,, ,,	11	2	
16	1st Sept. ,,	10th ,, ,,	9	1	
17	9th ,, ,,	20th ,, ,,	11	1	
18	9th Oct. ,,	19th ,, ,,	10	1	

Appendix III-E—*contd.*

Serial No.	Date of pupation	Date of emergence	Pupal period in days	No. of individuals under observation	Remarks	
(iii) At 75° F. and humidity 50 per cent						
1	4th Aug. 1937	14th Aug. 1937	10	2		
2	9th ,, ,,	19th ,, ,,	10	1		
3	17th ,, ,,	29th ,, ,,	12	11	Maximum	12 days
4	18th ,, ,,	29th ,, ,,	11	1	Minimum	10 days
5	20th ,, ,,	31st ,, ,,	11	1	Average	10·4 days
6	22nd ,, ,,	1st Sept. ,,	10	1		
(iv) At 68°F. and humidity range from 72-80 per cent						
1	31st Aug. 1937	15th Sept. 1937	15	1		
2	5th Oct. ,,	26th Oct. ,,	21	1		
		Average	18	days		
(v) At 68°F. and humidity 50 per cent						
1	5th Aug. 1937	20th Aug. 1937	15	1		
2	8th ,, ,,	24th ,, ,,	16	1		
3	9th ,, ,,	26th ,, ,,	17	1	Maximum	19 days
4	11th ,, ,,	26th ,, ,,	15	1	Minimum	15 days
5	21st ,, ,,	9th Sept. ,,	19	1	Average	16·8 days
6	23rd ,, ,,	11th ,, ,,	19	1		
(vi) At 62°F. and humidity 90 per cent						
1	8th Sept. 1937	3rd Oct. 1937	25	1	Maximum	29 days
2	9th ,, ,,	4th ,, ,,	25	1	Minimum	25 days
3	12th ,, ,,	11th ,, ,,	29	1	Average	26·3 days

2. *At Quetta*

Serial No.	Date of pupation	Date of emergence	Pupal period in days	No. of individuals under observation	Remarks
1	26th June 1937	9th July 1937	13	1	
2	26th ,, ,,	11th ,, ,,	15	2	
3	29th ,, ,,	10th ,, ,,	11	1	
4	29th ,, ,,	12th ,, ,,	13	2	
5	29th ,, ,,	13th ,, ,,	14	1	
6	3rd July ,,	12th ,, ,,	9	1	July
7	6th ,, ,,	19th ,, ,,	13	1	Maximum 15 days
8	9th ,, ,,	18th ,, ,,	9	1	Minimum 8 days
9	9th ,, ,,	20th ,, ,,	11	1	Average 12 days
10	12th ,, ,,	25th ,, ,,	13	1	
11	13th ,, ,,	23rd ,, ,,	10	1	
12	14th ,, ,,	28th ,, ,,	14	1	
13	15th ,, ,,	24th ,, ,,	9	1	
14	15th ,, ,,	28th ,, ,,	13	3	
15	16th ,, ,,	24th ,, ,,	8	1	
16	16th ,, ,,	26th ,, ,,	10	1	
17	18th ,, ,,	31st ,, ,,	13	1	
18	23rd ,, ,,	3rd Aug. 1937	11	1	August
19	24th ,, ,,	5th ,, ,,	12	1	Maximum 12 days
20	25th ,, ,,	4th ,, ,,	10	1	Minimum 9 days
21	29th ,, ,,	7th ,, ,,	9	1	Average 10 days
22	31st ,, ,,	9th ,, ,,	9	2	
23	2nd Aug. ,,	11th ,, ,,	9	1	
24	7th ,, ,,	17th ,, ,,	10	1	
25	10th ,, ,,	19th ,, ,,	9	1	

Serial No.	Date of pupation	Date of emergence	Pupal period in days	No. of individuals under observation	Remarks
26	14th Aug. 1937	24th Aug. 1937	10	1	
27	19th ,, ,,	28th ,, ,,	9	1	
28	28th ,, ,,	7th Sept. ,,	10	1	September
29	28th ,, ,,	9th ,, ,,	12	1	Average 11 days

3. *At Fort Sandeman*

1	6th Sept. 1937	15th Sept. 1937	9	1	September
2	6th ,, ,,	16th ,, ,,	10	1	Maximum 11 days
3	7th ,, ,,	15th ,, ,,	8	2	Minimum 6 days
4	8th ,, ,,	15th ,, ,,	7	1	Average 8·1 days
5	8th ,, ,,	16th ,, ,,	8	1	
6	9th ,, ,,	15th ,, ,,	6	1	
7	9th ,, ,,	16th ,, ,,	7	1	
8	9th ,, ,,	18th ,, ,,	9	1	
9	9th ,, ,,	20th ,, ,,	11	1	
10	10th ,, ,,	18th ,, ,,	8	1	
11	11th ,, ,,	17th ,, ,,	6	1	
12	14th ,, ,,	24th ,, ,,	10	1	
13	16th ,, ,,	23rd ,, ,,	7	1	

Appendix IV

NUMBER OF FRUITS FOUND DAMAGED BY CODLING MOTH AT VARIOUS STATIONS AT DIFFERENT TIMES OF THE YEAR

Observations		No. of trees sampled	No. of fruit examined		No. showing damage by Codling moth		Percentage of damaged fruit		No. of damaged fruit dissected		Percentage of damaged fruit containing codling moth larvae	
Month	No. of observations		Ground	Tree	Ground	Tree	Ground	Tree	Ground	Tree	Ground	Tree
A. Apple												
Station No. 1. Quetta (Forest Reserve and Arbab Shah Nawaz's garden)												
Variety of apple under observation, Kulu												
15th—30th June 1937	3	9	314	344	304	604	97	71	299	424	13	30
July 1937	4	5	202	879	185	606	92	69	185	534	6	13
August 1937	4	7	222	666	193	594	87	89	193	509	4	12
September 1937	5	19	308	748	287	639	93	85	287	556	3	7
1st—15th October 1937	2	5	142	194	136	173	96	89	136	161	0·5	0·5
Variety of apple under observation, Kandhari												
15th—30th June 1937	2	2	254	238	183	154	72	65	178	139	21	48
July 1937	4	4	198	441	173	371	87	84	173	270	7	17
August 1937	4	7	230	646	205	539	68	83	205	463	5	10
1st—15th September 1937	2	9	100	256	77	144	77	56	117	124	...	5
Station No. 2. Quetta (Residency garden, Malik Jan Mohd.'s garden, Revenue Commissioner's garden, Patel's garden and Arbab Mohd. Umer's garden)												
Variety of apple under observation, Kulu												
15th—30th June 1937	3	6	242	924	224	808	93	87	224	723	8	24
July 1937	4	5	134	515	132	457	98	89	132	320	8	30
August 1937	3	6	74	372	64	292	86	88	62	262	3	10
1st—15th September 1937	3	6	93	182	83	150	90	82	88	150	4	8

Appendix IV—*contd.*

Observations		No. of trees sampled	No. of fruit examined		No. showing damage by Codling moth		Percentage of damaged fruit		No. of damaged fruit dissected		Percentage of damaged fruit containing Codling moth larvae	
Month	No. of obser-vations		Ground	Tree	Ground	Tree	Ground	Tree	Ground	Tree	Ground	Tree
Variety of apple under observation, Kandhari												
15th—30th June 1937	1	1	12	86	12	53	100	62	12	44	33	45
July 1937	3	3	114	368	97	326	85	89	97	263	1	10
August 1937	4	9	276	874	222	724	80	83	219	593	1	12
September 1937	5	21	362	768	246	471	68	61	246	424	2	4
Variety of apple under observation, Kashmiri												
2nd half of July 1937	1	1	26	40	26	39	100	98	26	31	31	45
August 1937	2	4	60	274	51	227	85	83	51	184	16	11
Variety of apple under observation, Shaker Séb												
June 1937	1	2	...	274	...	203	...	74	...	171	...	26
Station No. 4. Mastung (The Political Agent's garden, Assistant Political Agent's garden and Shahi Bagh)												
Variety of apple under observation, Kulu												
July 1937	2	6	46	324	41	297	89	92	41	244	8	18
August 1937	1	4	24	112	17	69	71	62	17	59	...	7
September 1937	1	3	44	104	43	94	98	91	43	82	2	7
Variety of apple under observation, Kandhari												
July 1937	2	4	40	314	38	260	95	83	38	194	6	14
August 1937	1	3	120	142	92	108	77	76	92	98	1	5
September 1937	1	3	20	120	11	37	31	55	11	37	...	5
Variety of apple under observation, Shaker Séb												
July 1937	2	3	...	68	...	49	...	72	...	49	...	4
Variety of apple under observation, Kashmiri (cooking)												
July 1937	2	7	6	74	...	44	...	59	...	44	...	...

Station No. 5. Karez Inayat Ullah												
Variety of apple under observation, Kulu												
June 1937 . .	1	2	60	391	55	319	92	82	55	319	62	34
July 1937 . .	1	2	28	128	27	114	97	89	27	64	37	58
August 1937 . .	1	4	28	62	28	50	100	81	28	50	4	8
September 1937 .	1	4	22	72	21	53	96	74	21	53	...	4
October 1937 . .	1	3	50	84	47	75	94	90	47	75	1	1
Variety of apple under observation, Kandhari												
June 1937 . .	1	1	58	240	53	197	92	83	53	197	41	48
July 1937 . .	1	2	76	260	71	228	94	88	71	149	3	31
August 1937 . .	1	2	50	80	50	70	100	88	50	60	6	8
September 1937 .	1	2	25	84	15	38	60	45	15	38	...	8
October 1937 . .	1	4	40	146	21	96	53	66	21	96	...	1
Station No. 6. Killa Abdullah												
Variety of apple under observation, Kulu												
July 1937 . .	1	2	38	176	38	142	100	81	38	78	5	22
August 1937 . .	1	2	64	176	64	165	100	94	64	145	11	8
September 1937 .	1	2	26	66	26	56	100	85	26	56	...	5
Variety of apple under observation, Kandhari												
June 1937 . .	1	3	320	420	269	388	85	92	244	363	16	21
July 1937 . .	1	2	56	166	46	98	82	59	46	47	9	14
August 1937 . .	1	2	52	132	47	109	91	83	47	109	4	4
September 1937 .	1	1	12	64	9	48	75	75	9	48	...	4
Station No. 7. Killa Sakan Khan (Sardar Gulam Mohd. garden)												
Variety of apple under observation, Kulu												
June 1937 . .	1	2	8	164	6	141	75	86	6	111	...	39
July 1937 . .	1	2	50	132	48	123	96	93	48	72	2	36
August 1937 . .	1	3	8	56	8	48	100	86	8	48	25	8
September 1937 .	1	3	24	63	24	50	100	80	24	50	...	8

Appendix IV—*contd.*

Observations.		No. of trees sampled	No. of fruit examined.		No. showing damage by Codling moth		Percentage of damaged fruit		No. of damaged fruit dissected		Percentage of damaged fruit containing Codling moth larvae	
Month.	No. of obser-vations.		Ground.	Tree	Ground	Tree	Ground.	Tree.	Ground	Tree	Ground	Tree
Variety of apple under observation, Kandhari												
June 1937 . .	1	2	52	388	40	355	77	92	40	330	15	21
July 1937 . .	1	2	160	220	144	159	90	73	144	81	6	22
August 1937 . .	1	2	94	48	82	41	88	86	82	41	10	10
September 1937 .	1	3	110	48	99	42	90	88	99	42	1	7
October 1937 . .	1	2	98	...	63	...	65	...	63	...	...	...
Variety of apple under observation, Kashmiri												
June 1937 . .	1	2	16	130	16	125	100	93	16	100	38	29
July 1937 . .	1	2	46	150	46	138	100	92	46	98	...	...

Station No. 9. Fort Sandeman (Political Agent's gardens)

Variety of apple under observation, Kulu

June 1937 . .	4	35	987	9,050	735	4,095	74	45	987	40	46	60
July 1937 . .	4	40	1,970	5,100	1,786	2,670	91	52	1,970	40	3	25
August 1937 . .	3	25	602	1,672	569	892	94	53	602	135	2	8
1st—15th September 1937	2	20	36	229	30	186	83	81	31	155	...	3

B. Pears

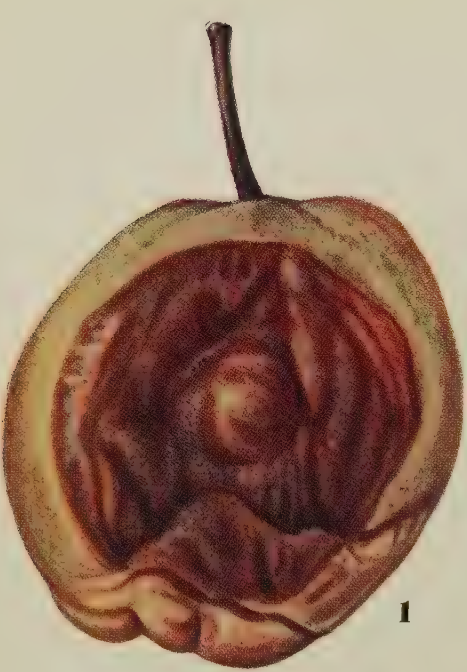
Station No. 9. Fort Sandeman (Political Agent's gardens)

June 1937 . .	4	40	998	8,610	665	3,276	67	39	998	40	9	45
July 1937 . .	4	40	1,718	4,605	1,594	2,590	93	56	1,718	40	3	30
August 1937 .	3	30	805	2,855	669	1,155	83	40	805	30	2	17

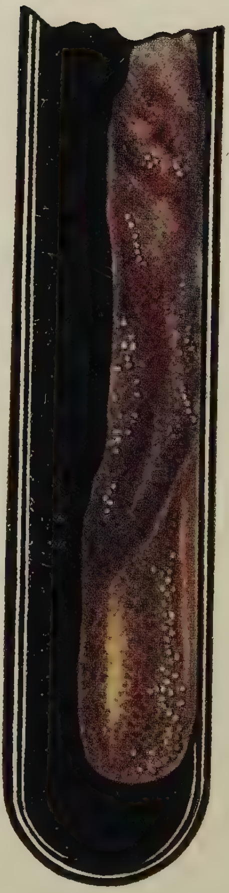
C. Quinces

Station No. 9.

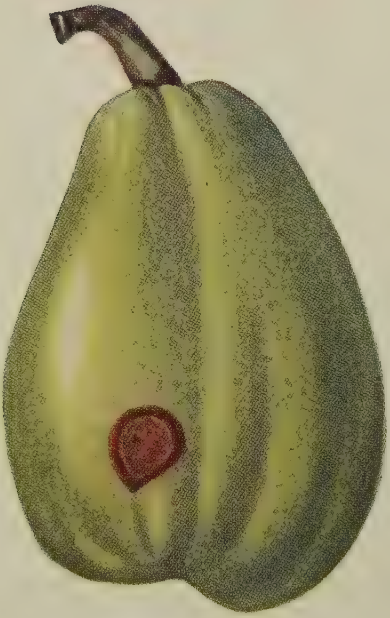
August 1937 . .	4	14	137	1,284	133	1,097	98	85	133	206	9	26
September 1937 .	4	18	57	615	54	603	95	98	57	164	4	23



1



3



2

FIG. 1. Pear fruit, natural infection, advanced stage

FIG. 2. Pear fruit, artificial infection, early stage

FIG. 3. Culture of the causative organism showing sclerotia

A NOTE ON SOFT ROT OF PEARS CAUSED BY A SPECIES OF '*ASPERGILLUS*

BY

H. H. PRASAD

Assistant to the Imperial Mycologist

(Received for publication on 23rd December 1937)

(With Plate XXV)

Introduction

During the months of July to November large quantities of pears are sold in Delhi market. These are both local produce and imported fruit from the North-West Frontier Province. Local produce ceases to come after September.

Many pears are found to have soft, moist spots varying in circumference from ¼ to 1 inch. The spots are water-soaked in appearance and of brown coloration. When they occur on fruits of greenish yellow tinge the contrast between colour of skin on the healthy portion and on the diseased portion is very marked ; as the fruits are kept for a few days, the spotted portion becomes sunken and the skin develops a blistered appearance. The spots increase in size rapidly and within four or five days, in the summer months, the whole fruit is rotten. Microscopic examination of the diseased tissues, even in the earliest cases of the disease, reveals the presence of fungus mycelium interwoven inside. Occasionally a superficial mould growth is evident at the centre of the infected area, which evidently appears to be the point of ingress for the causative organism.

Isolation from diseased material

Fruits showing diseased areas were surface-sterilized with 0·1 per cent mercuric chloride solution. Small portions of tissue were removed aseptically and placed on agar. Almost invariably one type of fungal colony resulted. Single-spore cultures were obtained by the dilution plate method.

Infection experiments

Healthy pears were surface-sterilized by means of rectified spirit and small punctures were made with a sterile needle. Small portions of agar cultures of the fungus were introduced at the punctures, and an equal number of fruits were kept uninoculated as controls. The fruits were wrapped in sterilized papers and kept at room temperature (roughly 27° C. to 32° C.).

After two days small roundish water-soaked spots developed at the point of inoculation. In the case of uninoculated fruits a blackish scar only developed. The diseased spots, which extended in area rapidly, gradually assumed a brown colour surrounded by a halo of brighter colour. Within four or five days the whole fruits were reduced to pulpy masses giving off a bad odour. At the point of puncture a small amount of aerial mycelium developed. All the diseased tissue beneath the epidermis was loaded with fungal mycelium.

Observations made during the progress of certain infection tests indicated that rotting of the tissue of the fruit occurred well in advance of the hyphal invasion. Fruits with undamaged skin failed to take infection artificially.

Morphology of the fungus

Following is a description of a young culture on Quaker Oat agar :—

Mycelium.—Creeping, branched, septate, hyaline, granular, varying in width from 3 to 7μ. Aerial mycelium scanty.

Conidiophore.—Erect, non-septate, simple, yellowish-brown, thick-walled smooth, bearing distinct, enlarged foot cells ; inflated capitately to form a globular or oval vesicle measuring 18-83μ in diameter, studded on all sides with closely-set sterigmata in one series measuring 6-15μ in length.

Conidia.—Catenulate, dark brown in the mass, light brown or chocolate when observed singly. Conidia sub-globose or globose, measuring 3·5 to 5·0μ distinctly echinulate.

Sclerotia.—Formed in old cultures, greyish to light chocolate in colour, sub-globose to globose, measuring 300 to 528μ.

The fungus grows readily on various agar media between *p*H 3·3 and 8·0.

Identity of the fungus

It is clear from the above characteristics that the fungus belongs to the black Aspergilli. According to the classification of Thom and Church [1926] the persistence of colour bars, the size of conidia and presence of sclerotia places the fungus as a close relative of *A. japonicus* Saito. It is pointed out by Thom and Church that no culture they have received has been found to have characters identical with those given by Saito [1906], but they accept the species. The culture isolated from pears corresponds closely in all characteristics, except size of sterigmata, which are 6-15μ in length as compared with 7-9μ in Saito's description. The fungus would appear to be a form of *A. japonicus* Saito.

SUMMARY

(1) Severe rotting of pears occurs in Delhi market.

(2) Damage is due to a fungus which enters as a wound parasite and under favourable conditions can rot pears completely in four or five days.

(3) The fungus bears a close resemblance to *Aspergillus japonicus* Saito.

ACKNOWLEDGMENTS

Many thanks are due to Dr. G. Watts Padwick for kindly going through the manuscript and for many valuable suggestions. I also wish to acknowledge the help received from Messrs. L. S. Subramaniam and K. F. Kheswalla.

REFERENCES

Saito, K. (1906). *Bot. Mag.* (*Tokyo*) **20** (233), 61-63

Thom and Church (1926). 'The Aspergilli'. Baltimore. The Williams Wilkins Company

OBSERVATIONS ON THE MILLING OF RICE IN THE UNITED PROVINCES

(SUPPLEMENTARY NOTE)

BY

R. L. SETHI, M.Sc., B.Sc., (Edin.), I.A.S.

B. L. SETHI, M.Sc., Ph.D. (Wales)

T. R. MEHTA, B.Sc.

AND

P. S. GUPTA, M.Sc. (Luck.), M.Sc. (Lond.)

In the above paper [Sethi *et al.*, 1937] in the table on page 722 in the analysis of variance, 'Error' is based on 18 Degrees of Freedom. The supposition that 'Replications' can be taken out as a separate item is not valid in the present instance in analogy with 'blocks' in a randomised block arrangement. To estimate a valid error, it is desirable in this case to consider 'Replications' and all interactions involving 'Replications' to constitute 'Error' which will then make up 72 Degrees of Freedom.

On this basis the analysis of variance will be :—

Analysis of Variance

Due to	Degrees of Freedom	Sum of Squares	Mean Square	$\frac{1}{2}$ $\log_e$ (Mean Square)
Varieties	3	1,801·01	600·34**	3·1987
Methods	1	312·13	312·13**	2·8717
Seasons	2	1,646·13	823·07**	3·3565
Varieties × methods . . .	3	615·04	205·01**	2·6616
Varieties × seasons . . .	6	956·86	159·48**	2·5359
Seasons × methods . . .	2	326·98	163·49**	2·5484
Varieties × methods × seasons .	6	429·28	71·55	2·1352
Error	72	2,385·78	33·14	1·7504
Total .	95	8,473·21	..	..

The items marked ** are significant at $P = 0 \cdot 01$.

In the table on page 728 of the same paper the analysis was not based on individual observations. On the basis of 128 individual observations the analysis of variance will be as follows :—

Analysis of Variance

Due to	Degrees of Freedom	Sum of Squares	Mean Square	½ log$_e$ (Mean Square)
Appliances	3	1,534·38	511·46*	3·1186
Methods	1	1,839·97	1,839·97*	3·7587
Culture	1	18·22	18·22	1·4512
Seasons	1	3,671·17	3,671·17*	4·1042
Appliances × methods . . .	3	640·30	213·43*	2·6816
Appliances × culture . . .	3	44·81	14·94	..
Appliances × seasons . . .	3	573·35	191·12*	2·6264
Methods × culture	1	1·56	1·56	..
Methods × seasons	1	178·84	178·84*	2·5943
Culture × seasons	1	62·03	62·03*	2·0638
Appliances × methods × culture .	3	25·84	8·61	..
Appliances × culture × seasons . .	3	182·01	60·67*	2·0527
Appliances × methods × seasons .	3	625·26	208·42*	2·6698
Methods × culture × seasons . .	1	0·11	0·11	..
Appliances × methods × culture × seasons	3	46·84	15·61	..
Error	96	1,469·23	15·30	1·3639
Total .	127	10,913·92	..	..

Items marked* are significant at $P = 0 \cdot 05$.

REFERENCE

Sethi, R. L.; Sethi, B. L.; Mehta, T. R. and Gupta, P. S. (1937). *Ind. J. Agric. Sci.* 7, 713-732

THE MAYNARD-GANGA RAM PRIZE

APPLICATIONS are invited for the Maynard-Ganga Ram Prize of the value of Rs. 3,000 which will be awarded for a discovery, or an invention, or a new practical method tending to increase agricultural production in the Punjab on a paying basis. The prize is open to all, irrespective of caste, creed or nationality and Government servants are also eligible for it. Essays and theses are not eligible for competition and applicants should prove that some part of their discovery, invention, etc., is the result of work done after the prize was founded in 1925. The Managing Committee reserves to itself the right of withholding or postponing the prize, if no satisfactory achievement is reported to it. All entries in competition for the next award should reach the Director of Agriculture, Punjab, on or before the 31st December, 1938.

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Periodical Abstracts

Lists of publications and papers on Soil Science published in the Empire Overseas in—

	Price *s.*	*d.*
1933	1	0
1934	1	0
Soil Research in the British Empire published during 1935	1	0
Lists of Publications relating to Soils and Fertilisers—		
Published monthly, per annum, post free	10	0
Monthly Letters—		
Free to recipients, within the British Empire, of 'Publications relating to Soils and Fertilisers.' Subscription, outside the Empire, per annum	4	0
Recent Developments in Soil Analysis—		
Quarterly Supplement to the above publications. Separate copies each	0	6

Occasional Papers

	s.	*d.*
Technical Communications—		
34. Tropical Soils in relation to Tropical Crops	2	6
Annual Report: For the year 1934-35	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions (by the late Sir J. B. Harrison)	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1931-34	25	0

II. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL HEALTH, VETERINARY RESEARCH LABORATORY, NEW HAW, WEYBRIDGE, SURREY

Abstracting Journal

	s.	*d.*
The Veterinary Bulletin—		
1931. Vol. 1. Quarterly (1st Number, April)	7	6
Annual subscription	20	0
Subsequent volumes. Monthly (1st Number, January)	5	0
Annual subscription (postage paid)	40	0

Indexing Publication

	Price s.	d.
Index Veterinarius—Four issues a year. First issue April 1933— Annual subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed	100	0

III OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL NUTRITION, ROWETT RESEARCH INSTITUTE, BUCKSBURN, ABERDEEN

Journal

Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)—

	s.	d.
Subscription per volume of 4 numbers	42	0
Per single number	13	0

Occasional Papers

	s.	d.
Technical Communications—		
7. Wheat : Pre-eminence as a Cereal Food, Nutritive Value ; Relation to Health and Disease	1	0
Occasional Communications—		
1. The Effect of Climate on the Composition of Pasture Plants.		

IV. OBTAINABLE FROM THE IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS, PLANT BREEDING INSTITUTE, SCHOOL OF AGRICULTURE, CAMBRIDGE

Journal

Plant Breeding Abstracts—

	s.	d.
Quarterly. Annual subscription	15	0
Single copies	5	0

Occasional Papers

	s.	d.
Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932-1935. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication of the Imperial Bureaux of Plant Genetics)	10	0
Bibliographical Monographs—		
The Experimental Production of Haploids and Polyploids	5	0
Breeding Resistant Varieties, 1930-33 (Supplement)	2	0
An Outline of Cytological Technique for Plant Breeders	1	6

V. OBTAINABLE FROM THE IMPERIAL BUREAU OF PASTURES AND FORAGE CROPS, WELSH PLANT BREEDING STATION, AGRICULTURAL BUILDINGS, ALEXANDRA ROAD, ABERYSTWYTH, WALES

Journals

	Price. s.	d.
Herbage Abstracts—		
Quarterly. Annual subscription	15	0
Single numbers	5	0
Herbage Reviews—		
Subscription is at present—Vol. 1 (1933), Vol. 2 (1934), Vol. 3 (1935), Vol. 4 (1936)—included in the Herbage Abstracts		

Occasional Papers

	s.	d.
Bulletins—		
19. Production of Grass Seed	5	0
20. Insects and Other Pests Injurious to the Production of Seed in Herbage and Forage Crops, H. F. Barnes	2	6
21. The Influence of Climatic Conditions on Type Composition. Nils Sylvén	1	0
22. Technique of Grass Seed Production at Welsh Plant Breeding Station. Gwilym Evans	5	0
23. Production of Legume Seed	5	0
24. Collection of Native Grass Seed in the Great Plains, U. S. A. F. J. Crider and M. M. Hoover	2	0

VI. OBTAINABLE FROM THE IMPERIAL BUREAU OF HORTICULTURE AND PLANTATION CROPS, EAST MALLING RESEARCH STATION, EAST MALLING, KENT

Journal

	s.	d.
Horticultural Abstracts—		
A quarterly abstract publication of current horticultural literature—		
Annual subscription	15	0
Single copy	4	0

Technical Communications

	s.	d.
8. Horticultural Aspects of Wooly Aphis Control together with a Survey of the Literature. R. M. Greenslade	2	6

Occasional Papers

	s.	d.
5. The Frameworking of Fruit Trees. R. J. Garner and W. F. Walker, 1938	1	0
Other Publications—		
Index to Volumes I—X of the *Journal of Pomology and Horticultural Science*, 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science*. Available from the Bureau	5	0
Old and New Standpoints on Senile Degeneration, 1931. By A. P. C. Bijhouwer	0	6

VII. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL BREEDING AND GENETICS, INSTITUTE OF ANIMAL GENETICS, UNIVERSITY OF EDINBURGH, KING'S BUILDINGS, WEST MAINS ROAD, EDINBURGH

Journal

	Price	
	s.	*d.*
Animal Breeding Abstracts (Quarterly). Commencing April, 1933. Annual subscription	15	0

Occasional Papers

	s.	*d.*
Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0

VIII. OBTAINABLE FROM THE IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY (HELMINTHOLOGY), INSTITUTE OF AGRICULTURAL PARASITOLOGY, WINCHES FARM DRIVE, HATFIELD ROAD, ST. ALBANS, HERTS

Journals

	s.	*d.*
Bibliography of Helminthology. For the year 1933—		
Library edition, bound in cloth	10	6
Stiff paper cover only	8	0
Helminthological Abstracts. (Issued in five or six parts per volume, each volume covering the literature of a single year.) Subscription per volume, payable in advance	30	0
Completed volumes bound in cloth	32	0

Occasional Papers

	s.	*d.*
The Effects of some Natural Factors on the Second Ecdysis of Nematode Infective Larvae. By G. Lapage. 25 pp.	4	0
Notes and Memoranda—		
11. Recent Developments in the Control of *Heterodera marioni*. 6 pp	1	6

PUBLICATIONS ISSUED BY THE IMPERIAL INSTITUTE OF ENTOMOLOGY, 41, QUEEN'S GATE, LONDON, S. W. 7

	s.	*d.*
Bulletin of Entomological Research.—Published quarterly and containing original articles on Economic Entomology. Issued post-free. Annual subscription (payable in advance)	30	0

Review of Applied Entomology.—Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series. Series 'A' dealing with insect and other arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin, Series 'B' dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post-free.

	Series 'A' *s.*	Series 'B' *s.*
Annual subscription (payable in advance)	30	15
Vol. XXIII (1935)	42	21

Zoological Record—Part Insecta.—Published annually about July in each year and containing as complete a record as possible of the literature of the previous year chiefly from the systematic standpoint.

	s.	*d.*
Annual subscription (including postage)	15	6
Report of the Fourth Imperial Entomological Conference, 19—27th September 1935	4	0

PUBLICATIONS OBTAINABLE FROM THE IMPERIAL MYCOLOGICAL INSTITUTE, KEW, SURREY

Journal

Review of Applied Mycology.—Annual subscription, 12 monthly parts, with title page and index (post-free)	21	0
Single part	2	0
Title page and index	3	0
Report on the Third Imperial Mycological Conference, 1934 . . .	2	0

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian Postage]

1. Agriculture and Live-stock in India

ICAR. 1 A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the Tropics. (Established 1931. Published in January, March, May, July, September and November. Prepayable subscription Rs. 6 or 9*s*. 9*d*. per annum. Price per part Rs. 2 or 3*s*. 6*d*.) Volumes I to VII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5. A bi-monthly scientific journal of agriculture and the allied sciences mainly devoted to the publication of the results of original research and field experiments. (Established 1931. Published in February, April, June, August, October and December. Prepayable subscription Rs. 15 or 24*s*. per annum. Price per part Rs. 3 or 5*s*. 3*d*.) Volumes I to VII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6. A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931. Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s*. 9*d*. Price per part Rs. 2 or 3*s*. 6*d*.) Volumes I to VII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10·1 No. 1. The Fungi of India, By E. J. Butler, C.I.E., D.Sc., M.B., F.R.S., and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s*.

ICAR. 10·2 No. 2. Life-histories of Indian Microlepidoptera, Second Series: Alucitidæ (Pterophoridæ, Tortricina and Gelechiadæ), By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s*. 6*d*.

ICAR. 10·3 No. 3. The Open Pan System of White-Sugar Manufacture, By R. C. Srivastava, B.Sc. (1935, 2nd edition.) Price Rs. 3-2-0 or 5*s*. 6*d*.

ICAR. 10·4 No. 4. Life-histories of Indian Microlepidoptera; Cosmopterygidæ to Neopseustidæ, By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S.(1933) Price Rs. 4-8-0 or 7*s*. 6*d*.

ICAR. 10·5 No. 5. The Bombay Grasses, By E. J. Blatter, S. J., Ph. D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. (1935). Price Rs. 20-12-0 or 32*s*. 6*d*.

ICAR. 10·6 No. 6. Helminth Parasites of the Domesticated Animals in India, By G. D. Bhalerao, M.Sc. (1935). Price Rs. 7-12-0 or 13*s*. 3*d*.

ICAR. 10·7	No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng. and the Isolation of Types Resistant to the Disease, By W. McRae, M.A., D.Sc. (Edin.), F.L.S. and F.J.F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s*. 3*d*.
ICAR. 10·8	No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy, By C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s*. 9*d*.
ICAR. 10·9	No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah-Shell Oil Storage and Distributing Company of India, Ltd., By C. P. G. Wade. (1935). Price Rs. 3-14-0 or 6*s*. 6*d*.
ICAR. 10·10	No. 10. The Spotted Bollworms of Cotton in South Gujarat, By B. P. Deshpande and N. T. Nadkarny, B.Ag. (1936). Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 10·11	No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus muscles and the formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations, By. H. N. Chelva Ayyangar, G.M.V.C. (1937). Price Rs. 4-10-0 or 7*s*. 9*d*.
ICAR. 10·12	No. 12. The Fungi of India, Supplement I. By B. B. Mundkur. (*In the Press*)

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8·1	No. 1. List of Publications on Indian Entomology, 1930, By the Imperial Entomologist, Pusa. (1934). Price As. 14 or 1*s*. 6*d*.
ICAR. 8·2	No. 2. List of Publications on Indian Entomology, 1931, By the Imperial Entomologist, Pusa. (1934). Price As. 8 or 10*d*.
ICAR. 8·3	No. 3. List of Publications on Indian Entomology, 1932, By the Imperial Entomologist, Pusa. (1934). Price As. 12 or 1*s*. 3*d*.
ICAR. 8·4	No. 4. Host Plant Index of Indo-Ceylonese Coccidae, By S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. (1934). Price Re. 1-10-0 or 2*s*. 9*d*.
ICAR. 8·5	No. 5. List of Publications on Indian Entomology, 1933, compiled by the Imperial Entomologist, Pusa. (1935). Price As. 9 or 1*s*.
ICAR. 8·6	No. 6. Bee-keeping, By C. C. Ghosh, B.A., F.E.S. (3rd Edition.) (1936). Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8·7	No. 7. List of Publications on Indian Entomology, 1934, compiled by the Imperial Entomologist, Pusa. (1935). Price Re. 1-2-0 or 2*s*.
ICAR. 8·8	No. 8. Selected Clinical Articles, Part I, By G. K. Sharma, G.P.V.C. and R. L. Kaura, B.V.Sc., M.R.C.V.S. (1936). Price As. 8 or 10*d*.
ICAR. 8·9	No. 9. Statistical Methods and their Application to Agronomy ; A bibliography, By. K. K. Guha Roy. (1936). Price Rs. 2-2-0 or 4*s*.
ICAR. 8·10	No. 10. Diseases of Sugarcane and Methods for their Control, By. L. S. Subramaniam. (1936). Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8·11	No. 11. Tables of Standard Errors of Mendelian Ratios, compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell) and P. Krishna Rao, L.Ag. (1936). Price As. 12 or 1s. 3*d*.
ICAR. 8·12	No. 12. List of Publications on the Botany of Indian Crops, Part II, for the period 1928-32, By R. D. Bose. (1936). Price Rs. 3-6-0 or 6*s*. 9*d*,

ICAR. 8·13	No. 13. Two New Statistical Tables based upon Fisher's '*t*', By M. Vaidyanathan. (1936). Price As. 6 or 8*d*.
ICAR. 8·14	No. 14. List of Publications on Indian Entomology (1935), compiled by the Imperial Entomologist, Pusa. (1937). Price Re. 1-4-0 or 2*s*.
ICAR. 8·15	No. 15. Selected Clinical Articles, Part II, By G. K. Sharma, G.P.V.C., R. L. Kaura, B.V.Sc., M.R.C.V.S., S. Ganapathy Iyer, G.M.V.C., G. S. Khan, B.Sc. and S. Mangrulkar, M.Sc., M.R.C.V.S., D.T.V.M. (EDIN.) (1937). Price Re. 1-4-0 or 2*s*.
ICAR. 8·16	No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders, by P. E. Lander, M.A., D.Sc., F.I.C., I.A.S. (1937). Price Rs. 3-14 or 6*s*. 9*d*.
ICAR. 8·17	No. 17. A Brief Survey of some of the Important Breeds of Cattle in India, by Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S., F.N.I. (1938). Price Rs. 2 or 3*s*. 6*d*.
ICAR. 8·18	No. 18. Milk Records of Cattle in Approved Dairy Farms in India, by K. P. R. Kartha, B. A. (*In the Press*).
ICAR. 8·19	No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province, by Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.) F.N.I. and H. N. Batra, B.Sc., Assoc. I. A. R. I. Price Re. 1 or 1*s*. 9*d*.
ICAR. 8·20.	No. 20. Report on an Enquiry into the Cultivation of Cloves in India, By A. K. Yegna Narayan Aiyer. Price Rs. 2-4-0 or 3*s*. 9*d*.
ICAR. 8·21	No. 21. Investigations on the Cold Storage of Mangoes, By G. S. Cheems, D.Sc., I.A.S., D. V. Karmarkar, M.Sc., Ph.D., A.I.I.Sc. and B. M. Joshi, M.Sc. (*In Press*)

6. Annual Reports of the Imperial Council of Agricultural Research

ICAR. 12·31	Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.
ICAR. 12·32	Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.
ICAR. 12·33	Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of Stock.)
ICAR. 12·34	Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Re. 1-8-0 or 2*s*. 6*d*.
ICAR. 12·35	Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.
ICAR. 12·36	Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.
ICAR. 12·37	Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Re. 1-2-0 or 2*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9·29	Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock.)
ICAR. 9·31	Review of Agricultural Operations in India, 1929-31. Price Rs. 5 or 8*s*. 3*d*.
ICAR. 9·33	Review of Agricultural Operations in India, 1931-33. Price Rs. 5-12-0 or 9*s*. 6*d*.

	Agriculture and Animal Husbandry in India, 1933-34 and 1934-35—
ICAR. 13-1-35	Part I.—Crop Production. Price Rs. 4-14-0 or 8*s.*
ICAR. 13-2-35	Part II.—Animal Husbandry. Price Re. 1 or 1*s.* 9*d.*
ICAR. 13·36	Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10 or 7*s.* 9*d.*

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2	Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s.* 6*d.*
ICAR. 3	Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s.* 9*d.*

9. Miscellaneous

VRI. 1	A Description of the Imperial Institute of Veterinary Research, Muktesar and its Sub-station, the Imperial Veterinary Serum Institute, Izatnagar, By F. Ware, F. R.C.V.S. Price Re. 1-4-0 or 2*s.*
ARI. 7. 187	The Production of Cigarette Tobacco by Flue-curing, By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S., and Kashi Ram. *Imp. Inst. Agri. Res., Pusa Bull.* No. 187. Reprinted (1935). Price Re. 1 or 1*s.* 9*d.*
ICAR. 16	A Handbook of Statistics for Use in Plant Breeding and Agricultural Problems, By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s.* 3*d.*
ICAR. 7	Report on the Work of the Imperial Council of Agricultural Research in Applying Sciences to Crop Production in India, By Sir John Russell, D.Sc., F.R.S. Price Re. 1-14 or 3*s.* 3*d.*
ICAR. 18	Report on the Development of the Cattle and Dairy Industries of India, By Norman C. Wright, M.A., D.Sc., Ph.D. Price Re. 1-8-0 or 2*s.* 6*d.*

Copies of the above publications can be had from :—

The Manager of Publications, Civil Lines, Delhi and from any of the Agents, a list of whom will be found on the inside page of the front cover.

Purchasers not residing in Asia, Africa and Australia should apply to the High Commissioner for India, India House, Aldwych, London. Prices include Indian postage and packing.

Note.—When indenting please give only the symbol preceding the name of the publication.

ORIGINAL ARTICLES

THE DESCRIPTION OF CROP-PLANT CHARACTERS AND THEIR RANGES OF VARIATION

BY

J. B. HUTCHINSON,

K. RAMIAH

AND

THE MEMBERS OF TWO SPECIAL SUB-COMMITTEES

WITH A FOREWORD

BY

W. BURNS

FOREWORD

THE improvement of crops by breeding is one of the most important and most successful activities of the Departments of Agriculture in India. Every crop botanist usually begins with a collection of varieties of the crop he is dealing with in his province or state, evolves more prolific strains of particular important varieties and at the same time builds up a collection of types. These types are classified and described mainly on morphological characters, though some information is usually included about some of the known physiological characteristics. Another botanist dealing with the same crop plant in a different province does the same thing for his types and such descriptions of types are published independently. Such unco-ordinated descriptions of types of the same crop plant from different centres are likely to lead to confusion and do not help on their real object, namely to give a list of the plant-breeding material available.

The classification and description of crop plants must be looked on as problems in applied genetics rather than in taxonomy. The immediate need is a change in the method of presenting the data. The data should not only be complete for each crop but should be so arranged as to simplify the handling of similar material in the future and facilitate comparison of crop varieties grown in different parts of India. It is considered that such a change can be secured by the description of certain characters in each crop plant rather than the types themselves, and that the publication of such records can best be in the shape of standardised tables and schedules.

These ideas took shape gradually during 1936 and 1937 in the course of discussions in the Advisory Board of the Imperial Council of Agricultural Research and certain of its committees. The absence of uniformity in the description of morphological characters of the rice crop, especially those relating to colour, was brought to the notice of the Rice Research Sub-Committee by Mr. Ramiah in 1936, when the progress reports of several rice schemes came up for discussion. Mr. K. Ramiah later prepared notes and special colour plates to describe the range of variability in certain characters of rice. These notes and the general question of description of types in various crop plants were considered again by the Imperial Council of Agricultural Research and discussed at the Botanical Sub-Committee at its meeting in January, 1937. At this meeting Mr. J. B. Hutchinson (now Cotton Geneticist, Trinidad) gave a very clear exposition of the principles to be followed in the description of variability in crop plants and as a beginning it was resolved to constitute two small committees, one for cotton and the other for rice, and entrust them with the collection of information on the range of variability and the designing of special schedules for the characters to be studied in each of the two crops. The committee for cotton consisted of :—

Mr. J. B. Hutchinson (Convenor) (then Geneticist and Botanist, Institute of Plant Industry, Indore),

Rao Sahib G. L. Kottur, Cotton Botanist, Southern Division, Bombay Presidency,

Mr. V. Ramanatha Ayyar, Cotton Botanist, Madras,

Dr. Nazir Ahmad, Director, Technological Laboratory, Indian Central Cotton Committee, Matunga, Bombay, and

Mr. K. Ramiah (then Rice Specialist, Madras),
and for rice :—

Mr. K. Ramiah (Convenor) (then Rice Specialist, Madras),

Rao Sahib K. I. Thadani, Director of Agriculture, Sind,

Dr. S. K. Mitra, then Economic Botanist, Assam,

Mr. M. Alam, Rice Specialist, Bihar,

Dr. B. L. Sethi, then Rice Specialist, United Provinces,

Mr. B. S. Kadam, Crop Botanist, Bombay,

Mr. A. M. Thompson, Senior Marketing Officer, and

Dr. B. P. Pal, Imperial Economic Botanist.

The Committee for cotton met twice in Bombay in 1937 and the Committee for rice once in Delhi during 1937 and again in March 1938, and the notes now published are really the reports of the two Committees. The basis for the cotton report was a detailed note prepared by Mr. J. B. Hutchinson before he left India. For rice, the notes and charts that had been prepared by Mr. K. Ramiah for the Imperial Council of Agricultural Research meeting were employed. The original notes were subsequently enlarged into the present form by Mr. K. Ramiah, as a result of the discussions that had taken place at the Committee meetings and also by including opinions of persons not in the Committee, obtained by correspondence. The members of Mr. Hutchinson's Committee are indebted to Mr. V. G. Panse, Institute of Plant Industry, Indore, for the collection and analysis of the halo-length determinations given in Appendix III and for the preparation of the specimen schedules in Appendix IV of the cotton paper. The members of Mr. Ramiah's Committee are similarly indebted to Mr. C. R. Sreenivasan, Paddy Specialist, Madras, for revising some of the plates accompanying the rice report in the light of discussions that had taken place at the Committee meeting and to Mr. J. W. Grant, Rice Research Officer, Burma, for the drawings of the Burmese *maung.* Mr. Ramanatha Ayyar prepared all the plates accompanying the cotton report at Coimbatore and Mr. B. S. Kadam has been mainly responsible for compiling the data in Appendices III and IV of the rice report. Mr. J. B. Hutchinson, after taking up the appointment of Geneticist at the Cotton Research Station, Trinidad, continued by correspondence to give valuable help in completing these reports.

Their form, however, has been changed from that of reports into something more suitable for publication as scientific papers and they are now presented in the hope that they will give a lead to a universally useful system of description of the characters of crop plants.

W. BURNS
Agricultural Expert
Imperial Council of Agricultural Research,
India

20th May 1938

I. THE VARIABILITY OF INDIAN COTTONS

(Received for publication on 20th May 1938)

(With Plates XXVI-XXXVII)

Three species of *Gossypium* are cultivated for their cotton lint on a large scale in India :

G. arboreum L.
G. herbaceum L.
G. hirsutum L.

Their botanical classification has been dealt with by Hutchinson and Ghose [1937] and will not be discussed here. For studies of variability they may be considered as three independent groups. The botanical species of the several varieties of cotton recognised in trade in India is dealt with in Appendix I.

Two other species are cultivated on small areas in India, *G. religiosum* L. (Bourbon), which occurs as a component of the *Nadam* crop of Madras and Mysore, and *G. barbadense* L., which is grown to some extent in Sind. As these are both New World types, they are referred to briefly below.

G. arboreum L.

Hutchinson and Ghose [1937] divide the Indian types of *G. arboreum* into three varieties and three forms. Monopodial, usually perennial, forms are included in var. *typicum.* Of the sympodial, annual forms, most belong to var. *neglectum.* The long-bolled types of Assam belong to var. *cernuum.* Primarily on geographical grounds Hutchinson and Ghose distinguish three Indian forms of vars. *typicum* and *neglectum*, forma *indica*, *bengalensis* and *burmanica*. As all these types form a widely distributed, variable group which inter-breeds freely wherever its components come together, they are taken as a single unit for the study of variability.

G. herbaceum L.

All the Indian forms of *G. herbaceum* belong to var. *frutescens* Delile Wagad cotton which predominates in Cutch and Kathiawar is also included under var. *frutescens*, but in this the closed-boll type commonest in var. *typicum* first appears. These are predominantly monopodial annual types except the South Madras forms such as *Uppams*, which are sympodial.

G. hirsutum L.

The chief Indian types in this species may broadly be classified into three geographical races, (1) Punjab-American, (2) Dharwar-American and (3) Cambodia. They are mostly sympodial annuals, though some types develop strong monopodial branches at the base.

G. religiosum is perennial in habit, containing both monopodial and sympodial forms.

G. barbadense is frequently grown as a perennial tree in house compounds. The annual Sea Island and Egyptian forms are under cultivation in Sind. These can be distinguished from other American cottons by their pitted, tapering bolls which open imperfectly.

The principal commercial types of cotton grown in India and their botanical composition are given in Appendix I.

SIMPLY INHERITED CHARACTERS

A list of the simply inherited factor pairs so far recorded in the Asiatic and New World species is given in Appendix II. Gene nomenclature in *Gossypium* is at present under revision in consultation with American workers, and gene symbols are therefore omitted.

More than one allelomorph affecting the following characters occur in field crops :—

Corolla colour.
Leaf shape.
Anthocyanin pigment.
Leaf nectaries.
Lint colour.
Seed fuzz.
Pollen colour (New World only).

In all these characters the heterozygotes are more or less intermediate between the homozygotes. In most cases they are more easily distinguished from one homozygote than from the other. The one from which the heterozygote is less easily distinguished is usually called dominant.

In all other cases, except short lint and petalody dominance of the gene found in the field, is complete.

PLANT HABIT AND YIELD

The *arboreum* cottons vary from tall (8 ft.-12 ft.) bushy shrubs (var. *typicum*) to short (1 ft.-5 ft.) almost herbaceous plants, with no, or very few, vegetative branches (vars. *neglectum* and *cernuum*).

The *herbaceum* cottons of the Bombay Presidency develop stronger vegetative branches at the base and are longer in duration than the South Indian *Uppam*. They vary in height from 1½ ft. to 5 ft.

The *hirsutums* can be distinguished by their broad leaves, large bolls and big fuzzy seeds. Though they form their first fruiting branches early, they are very susceptible to shedding under Indian conditions and, where growth is vigorous, they develop strong vegetative branches. Their heights range from 1½ ft. to 6 ft.

Branching is of two kinds, monopodial vegetative branches and sympodial fruiting branches. The time of maturity is closely correlated with the size and bushiness of the plant. The onset of the reproductive phase is conveniently indicated by the node at which the first fruiting branch appears. The associated group of characters, monopodial development, point of emergence of the first fruiting branch on the main stem, size of plant and time of fruiting, usually give a good index of habit characters. The habit of shedding buds, flowers and bolls under adverse environmental conditions is common throughout the genus *Gossypium* and, where it occurs, has a profound effect on the primary habit characters listed above. The following may be recorded :—

Character	Definition
*Number of monopodia	Number of monopodial branches on the main stem. Short sprouts should not be included. A good limitation is to include only branches which have produced a flower bud on a secondary sympodium at first picking.
*Node Number	The number of the node from the base on the main stem (excluding the cotyledonary nodes) at which the first sympodial branch appears. Frequency distribution on at least 100 plants should also be included.
Plant height	To be measured from the cotyledonary node to the nearest cm. at maturity.
Number of internodes on the main stem.	To be counted at maturity.
Number of fruiting nodes	Number of nodes on sympodial branches prior to the commencement of picking.
Shedding percentage	The fruiting node count should be done in two parts : nodes at which shedding has not occurred and nodes at which shedding has occurred as a percentage of the whole. This is to be determined when the bolls start opening.
*Time of maturity	Percentage of the crop produced by two critical periods. For the *kharif* crops of northern India, percentages produced by December 1st and January 15th may be suggested. For South Indian cottons the percentage of the total crop picked during the first three weeks of pickings is appropriate. Length of the picking period, *i.e.*, dates of the first and last pickings should be given.
Yield	Total yield per acre.

The number of monopodia and the node number are usually closely correlated. The number of monopodia varies from none upwards and the node number from four to six upwards. In wild *arboreums*, plants may be found which develop monopodia indefinitely and never produce a sympodium on the main stem. In cultivated types, ten to fifteen monopodia and a node number of twenty to fifty are about the upper limit.

In *herbaceums* sympodia are produced from the seventh to the eighteenth nodes.

In *hirsutums* the node number varies from four to sixteen. It is reported that Cambodia has a node number of forty in Sind.

The early annual types which make up the Bengal and Oomras crops give from 25 to 100 per cent of their crop before December 1st and all of them give 80 to 100 per cent before January 15th. These dates do not apply to the cottons in South India where picking time varies according to the nature of the variety and the time of sowing. Under these conditions, a record of the proportion of *kapas* picked during the first three weeks of picking to the total yield may be more appropriate. Environmental variation in the time of maturity is considerable, but comparisons between strains grown at the same place and in the same year will be sufficiently accurate.

Yield is so greatly affected by environment that it can only be expressed satisfactorily as yield relative to a standard in a properly replicated experiment. It is desirable to give the average of three seasons.

LEAF AND STEM CHARACTERS

These include hairiness of leaves and stems, anthocyanin pigmentation of stems, leaf shape and leaf and extra-floral nectaries. The following may be recorded :—

Character	Definition
*Stem tip hairiness	According to grades given in Plates XXVI-XXIX.
*Stem pigmentation	According to grades given in Plates XXX and XXXI.
*Leaf shape	Five mature leaves on the main stem should be measured on each plant. Data should be given for (A) leaf length, (B) lobe length, (C) lobe width, (D) sinus length. The following indices should be given : $\frac{A}{C}$ and $\frac{A}{D}$ or $\frac{B}{C}$ and $\frac{B}{D}$ The first three or four leaves on the main stem are frequently broader than later ones, while young leaves change in shape as they mature. Measurements should be taken on mature leaves in the middle zone of the plant.
*Leaf and extra-floral nectaries	Number of nectaries per leaf and per flower (mean of five leaves and of five flowers on the main stem). Whether present (*a*) within the bracteoles, (*b*) outside the bracteoles, should be stated.
*Corolla colour	According to grades in plates prepared by Hutchinson and Harland (Plates XXXII and XXXIII). To be noted at 10 A.M.

The estimation of hairiness is a difficult matter. The whole plant may be completely glabrous. The upper or lower or both surfaces of the leaves may be hairy. Stems may be hairy throughout, or the hairs may be deciduous, leaving the older parts of the stem glabrous. *Arboreum* cottons are never so intensely hairy as *G. herbaceum* var. *frutescens*.

Cambodia is intensely hairy. The other two Upland races are less hairy.

G. barbadense has the fewest hairs on the stem.

Two types of hair occur. In some there are both simple and stellate hairs, and in others only stellate hairs.

Grades of hairiness of stem-tips are given in Plates XXVI-XXIX and data for stem tip grade should be supplemented by general notes on the hairiness of other plant parts.

The main pigmentation classes are those determined by the anthocyanin allelomorph series, and are described and illustrated by Hutchinson [1932]. In the normal spot class, which is that to which the great majority of the *arboreum* cottons belong, the intensity of pigmentation of the stem varies greatly. Stems may be quite green, slightly flushed with red or strongly pigmented. *Herbaceums* are usually green and Uplands green or slightly flushed. *Arboreums* vary from green to strongly pigmented. Grades are given in Plates XXX and XXXI, but the development of pigment and its intensity are influenced greatly on the extent of exposure to sunshine.

The measurement of leaf shape has been discussed by Leake [1911], Kottur [1923] and Hutchinson [1934], and the range of variation is given by the last author. He has also described the multiple allelomorph series which accounts for the main differences within the *arboreum* species, but there is sufficient variability in minor factors to justify the recording of measurements.

Nectaries may be present on from one to three of the main leaf nerves. Nectaries outside the bracteoles have only been recorded very rarely in Asiatic cottons, but are common in New World types.

BOLL CHARACTERS

These include the size and shape of the boll, weight of *kapas* (seed cotton) produced per boll, boll opening, ease of picking and risk of shedding of *kapas*.

Character	Definition
*Loculi per boll . . .	Mean number of loculi per boll on all bolls producing *kapas*, in the season crop.
*Length and breadth of mature bolls.	Mean of three mature (but unopened) bolls. On three-loculi bolls only, if possible, in Asiatics. If four-loculi bolls are included, they should be given separately. In Uplands, four-loculi bolls should be taken, and measurements for three-loculi bolls recorded separately, if necessary.
*Nature of boll surface. . .	Whether smooth or pitted.
*Type of opening . . .	According to grades in Plate XXXIV.
*Weight of *kapas* in grms. per 100 bolls.	To be determined from the total produce of the plant. It should be noted that the figure obtained will depend considerably on the proportion of four-loculi bolls, and, where adequate data are available, the total figure may suitably be supplemented by data for three-loculi and four-loculi bolls separately.

There is great variation in the extent of boll opening. Differences in *G. arboreum* depend chiefly on the factor pair described by Abraham [1934]. Ease of picking and tendency to shed *kapas* can only be described qualitatively.

It is suggested that loculi per boll and weight of *kapas* from 100 bolls should be determined on the total produce of the plant, because no easily selected sample of the plant produce is likely to represent accurately the performance of the plant as a whole. The mean number of loculi per boll is usually between 3·0 and 3·5 in *arboreum* cottons. Adequate data are not available for determining the range of boll size and weight of *kapas* per 100 bolls, but in these characters *cernuum* greatly exceeds the other *arboreums*.

The mean loculi number is between 3·0 and 3·4 in *herbaceums* and between 3·2 and 4·6 in *hirsutums*. In *G. barbadense* it is generally between 3·0 and 3·2. *Kapas* weight per boll is greatest in *G. hirsutum*.

KAPAS (SEED-COTTON) CHARACTERS

In this group may be included all the lint characters usually determined by plant breeders.

Character	Definition
*Lint colour . . .	The main difference is that between white and coloured due to a single factor difference. There is also a group of genes causing the development of a grey or light brown colour. Apart from the coloured-white difference, it is sufficient to grade *kapas* into white, grey and light brown. Commercial cottons will almost all fall in the white class and finer distinctions should be made only on lint samples sent for technological examination. (See under lint characters).
*Halo-length . . .	Since an enquiry into methods of measurement of halo-length at present in use in India (Appendix III) disclosed such very large variations in methods and in mean values obtained from them, the recording of halo-length can have no general value until some common method of measurement is adopted. In the meantime for purposes of record and exchange of information staple length as determined at the Technological Laboratory, Bombay, is the only estimate which can be recommended.
*Ginning percentage . .	To be determined from all the clean *kapas* produced on each plant. Where plant produce is small it will be more accurate to determine the ginning percentage from the *kapas* weight and seed weight than from the *kapas* weight and lint weight. If this is done, it should be stated.
*Weight of 100 seeds . .	To be determined from the weight and number of seeds produced on ginning all the clean *kapas* produced by the plant.
*Lint index	This can be determined from the data of the ginning percentage and weight of 100 seeds determinations. $\text{Lint index} = \frac{\text{Wt. of 100 seeds} \times \text{g. p.}}{100 - \text{g. p.}}$
*Tenacity of lint on seed .	To be noted on clean *kapas*.
*Fuzziness and the colour of fuzz.	According to grades given in Plates XXXV and XXXVI.

In order to study the differences in halo-length, when determined by different methods now in use in India, two sets of samples were distributed to plant breeders for halo-length determination and to the Director, Technological Laboratory, Bombay, for the determination of mean length by the Balls sorter. One set of samples was from *kapas* of a pure strain of Malvi 9 (*desi*) and one from *kapas* of a uniform lot of Dhar Cambodia (Upland). Data are given in Appendix III. For the estimation of ginning percentage, *kapas* should be thoroughly dried before ginning it.

The study of 'feel' is the only method at present available by which the plant breeder can judge the fineness of his material and a general record of 'feel' should always be given. It has been shown* that feel is associated more with the amount of wax present on the hair than with its fineness, although, as a rule, finer cottons are more waxy.

Apart from lintless types, ginning percentage ranges from ten to fifty per cent.

LINT CHARACTERS

In this group may be included the characters usually determined on lint samples by the technologist.

Character	Definition
Colour	To be determined on clean lint in two ways: (*a*) Grader's estimate of colour on a sample of clean lint. The trade classification is: white, white to creamy-white, creamy-white, creamy-white to creamy, and creamy. This will all be classed as white on the *kapas* colour standards. Highly coloured cottons like Coconada will be classed as brown or reddish brown. The trade also distinguishes bright and dull. (*b*) According to the standards given in Plate XXXVII. There are only three main colours, *viz.*, white, grey and brown. The genetic relationship among the grades shown has not yet been worked out, and it is probable that there is a number of modifiers in addition to two or three main genes.
Feel	According to grader's estimate.
Hair length	Mean length and length distribution from Balls or Baer sorter determinations.
Hair weight	Weight per inch, determined on whole hairs.
Maturity	Proportion of mature fibres to total number of fibres.
Spinning value . . .	Highest standard warp count, and actual lea strengths and counts spun.
Evenness of yarn and neppiness	Evenness class and number of neps per yard.

These characters should all be determined at the Indian Central Cotton Committee's Technological Laboratory, Matunga, by methods described in their publications.

---

*Indian Central Cotton Committee Technological Laboratory Bulletin (Series B), No. 18, 1933.

Mean hair length ranges from about ½ in. to 1¼ in. Hair weight ranges from 1·74 to 3·04 (10^{-6} oz.). Maturity is usually high in *arboreum* and *herbaceum* cottons. In *hirsutum* the percentage of dead fibres is comparatively higher. Spinning value (highest standard warp count) ranges from 6's to 40's.

ACCURACY OF ESTIMATION OF CHARACTERS

Before it becomes worth while describing a new strain of cotton in detail, varietal trials will usually have been carried out to determine its value compared with the standard of the tract. Such trials will usually be the Latin Square or randomised block type with five or six replications. Data from such trials are the most suitable for the compilation of a strain description. Plant characters should be measured on at least ten random plants per plot. A sample equivalent to four or five per cent of the mean number of plants per plot will be more adequate. Yield should, of course, be determined plot-wise. The plot size and number of replications should be such as to provide a ten-pound sample of lint for the measurement of lint characters and spinning value. Standard errors should be calculated wherever possible. In Appendix IV (*b*) and (*c*) are given descriptions of five sub-strains of Malvi 9 compared with Malvi 9 bulk as a standard to illustrate the use of a schedule drawn up on the basis of the characters described above.

These experiments should be conducted under normal conditions of cultivation and on the type of land on which cotton is usually grown in the tract. Information on the nature of the soil, on seasonal conditions (amount of rainfall, dates of incidence of frost and also the temperature and humidity ranges, if possible) and on cultural operations (rate and nature of manure, if applied, date of sowing, seed rate, average spacing between rows, and between plants, number of irrigations with intervals, if irrigated) should be given.

Since several characters, the principal of which is yield, are highly influenced by environmental conditions, the experiments should be repeated over at least three consecutive seasons. A standard strain of known relationship with the local cotton should be included in every trial.

Information on germination, resistance or susceptibility to known diseases and insect pests and to climatic conditions and any other information worth mentioning may be recorded in the remarks column of the schedule.

For strains of special interest it may be desirable to give descriptions on progeny row data only. Characters, for which a satisfactory estimate can be obtained from the mean of twenty-five plants, are marked above with an asterisk.

REFERENCES

Abraham, P. (1934). *Proc. Assoc. Econ. Biol.* (*Coimbatore*) **2**, 22
Hutchinson, J. B. (1932). *J. Genet.* **26**, 317
——— (1934). *J. Genet.* **28**, 437
Hutchinson, J. B. and Ghose, R. L. M. (1937). *Ind. J. Agric. Sci.* **7**, 233
Kottur, G. L. (1923). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **12**, No. 3
Leake, H. M. (1911). *J. Genet.* **1**, 224

Appendix I

LIST SHOWING THE BOTANICAL CLASSIFICATION OF THE TRADE VARIETIES UNDER THE *G. ARBOREUM* GROUP

Karunganni	*Gossypium arboreum* L. var. *neglectum* forma *indica*.
C. P. and Berar Verum	*Gossypium arboreum* L. var. *neglectum* forma *bengalensis*.
Hyderabad Gaorani	Mixture of *Gossypium arboreum* L. var. *neglectum*, forma *indica*, with *Gossypium hirsutum* L., the former constituting 70-80 per cent. Sometimes, a sprinkling of *Gossypium arboreum* L. var. *neglectum* forma *bengalensis* also occurs.
Westerns and Northerns other than Hagari I.	A mixture of *Gossypium herbaceum* L. var. *frutescens* and *Gossypium arboreum* L. var. *neglectum*, forma *indica*, the former being predominant in Westerns and the latter in Northerns.
Tinnevelly	*Gossypium arboreum* L. var. *neglectum* forma *indica*, mixed with a varying proportion of *Gossypium herbaceum* L. var. *frutescens*.
Salems	A mixture of *Gossypium arboreum* L. var. *neglectum*, forma *indica*, *G. arboreum* L. var. *typicum*, forma *indica*, *G. herbaceum* L. var. *frutescens*, and *G. religiosum* L.
Central India-Malvi and Nimari	Mixture of *Gossypium arboreum* L. var. *neglectum* forma *bengalensis* with *G. hirsutum* L., the latter forming about 60 per cent in Malvi and 10-40 per cent in Nimari.
C. P. No. 1 Oomras	Mixture of *G. arboreum* L. var. *neglectum* forma *bengalensis* with a small proportion of *G. arboreum* L. var *neglectum*, forma *indica* and *G. hirsutum*.
Broach-Kanvi	Mixture of *G. herbaceum* L. var. *frutescens* with a very small proportion of *G. arboreum* L. var. *neglectum*, forma *bengalensis*.
Banilla	Segregate of a cross between *G. arboreum* L. var. *neglectum*, forma *indica* with *G. arboreum* L. var. *cernuum*.
Coconadas and Warangal	*G. arboreum* L. var. *neglectum*, forma *indica*.
Bengals—N.-W. F. P.	Mixture of different types of *G. arboreum* L. var. *neglectum*, forma *bengalensis*.
C. P. No. 2 Oomras	Same as C. P. No. 1 but with a smaller proportion of *G. arboreum* L. var. *neglectum*, forma *indica*.
C. P. No. 3 Oomras	Same as C. P. No. 2 but with a larger proportion of *G. arboreum* L. var. *neglectum*, forma *bengalensis*.
Khandesh Oomras	Mixture of different types of *G. arboreum* L. var. *neglectum*, forma *bengalensis*.
Barsi and Nagar Oomras	Mixture of different types of *G. arboreum* L. var. *neglectum*, forma *bengalensis*, with a small proportion of *G. arboreum* L. var. *neglectum*, forma *indica* and *G. hirsutum* L.
Hyderabad Oomras	Same as Barsi and Nagar Oomras but with a higher proportion of *indica* and *hirsutum* components.

Dholleras—Matheo	Mixture of different types of *G. arboreum* L. var. *neglectum*, forma *bengalensis*.
Bengals—Baghelkhand and Bundelkhand	
Bengals—U. P.	
Bengals—Rajputana	
Bengals—Sind (*desi*)	
Bengals—Punjab (*desi*)	
Bengals—Bihar and Orissa	
Bengals—Western Bengal	
Burmas	*G. arboreum* L. var. *neglectum*, forma *burmanica*.
Comillas	Mostly *G. arboreum* L. var. *cernuum*.
Mungari	A mixture of a high proportion of *G. arboreum* var. *neglectum*, forma *bengalensis*, and small proportion of *G. arboreum* var. *neglectum*, forma *indica* and *G. herbaceum* var. *frutescens*.

LIST SHOWING THE BOTANICAL CLASSIFICATION OF THE TRADE VARIETIES UNDER THE *G. HIRSUTUM* GROUP

Cambodia including Co 2	*G. hirsutum*.
Punjab-American (289F and 4F)	
Sind-Sudhar	
Sind-American	
Dharwar-American including Gadag 1	
Hyderabad Gaorani	Contain *G. hirsutum* in varying proportions. Refer under *G. arboreum*.
Barsi and Nagar Oomras	
Central Provinces and Hyderabad Oomras.	
Malvi and Nimari	
Salems	Contain a small proportion of *G. religiosum*. Refer under *G. arboreum*.

LIST SHOWING THE BOTANICAL CLASSIFICATION OF THE TRADE VARIETIES UNDER THE *G. HERBACEUM* GROUP

Surat-Navsari	*G. herbaceum* L. var. *frutescens* Delile.
Broach	*G. herbaceum* L. var. *frutescens* Delile.
Dholleras	Consists of a *G. herbaceum* L. var. *frutescens* Delile and a *G. arboreum* L. var. *neglectum* component. The former component consists of a mixture of Wagad Lalio and Goghari, the latter component known as Matheo mixture is described under the *G. arboreum* groups.
Kumptas	*G. herbaceum* L. var. *frutescens* Delile.
Westerns	*G. herbaceum* L. var. *frutescens* Delile mixed with a small proportion of *G. arboreum* L. var. *neglectum*, forma *indica*.
Salems	See under *G. arboreum* group, the *herbaceum* component is known as Uppam.

Appendix II

SIMPLY INHERITED CHARACTERS

Character	Old World ($2n = 26$) cottons	New World ($2n = 52$) cottons
Chlorophyll deficiency	Green-chlorophyll deficient	Green-chlorophyll deficient duplicate Green-virescent yellow
Crumpling	Crumpled (complementaries)	
Crinkled dwarf		Normal-crinkled
Cluster habit		Normal-cluster
Short fruiting branches		Long-short sympodia
Leaf shape	Mutant broad	
	Mutant intermediate	
	Laciniated	Super-okra
	Narrow	Okra
	Broad	Normal
Leaf nectaries	Present—absent	
Anthocyanin	Spotted series :—	Spotted series :—
	Red plant body	
	Red leaf	Red leaf
	Red calyx	
	Red stem	Red stem
	Green stem	
	Spotless series :—	Spotless series :—
	Red leaf	Red leaf
	Red stem	Red stem
	Duplicate ex *G. anomalum*	Duplicate red Spotless
	Spot reducer	
Corolla colour	Yellow petal	Yellow
	Pale	Cream
	White	
	Pale, complementary	
	Pale, complementary (ex *G. anomalum*).	Yellow duplicate
	Yellow depressor	
Pollen colour	Yellow	Yellow
	Pale Cream complementary	Cream
Meristic variant	Increase in number of floral parts—normal	

Appendix II—*contd.*

SIMPLY INHERITED CHARACTERS—*contd.*

Character	Old World ($2n=26$) cottons	New World ($2n=52$) cottons
Sterility	Fertile—sterile	
Female sterility	Fertile—female sterile	
Petalody	Normal—petalodic	
Boll dehiscence	More dehiscent—less dehiscent	
Lint colour	Khaki-white (Duplicate) Light brown-white (Duplicate)	Khaki-white (Duplicate) Green-white.
Lintlessness	Hairy linted—glabrous lintless (complementary) Hairy linted—hairy lintless (complementary) Hairy linted—hairy lintless (sometimes lethal)	
Seed fuzz	Tufted—fuzzy	Naked (low lint index) —fuzzy (Upland) Tufted—naked (Peruvian) Less fuzzy—more fuzzy (Peruvian) Tufted—fuzzy (Upland)
Seed fuzz colours		Green-white Brown-white

Appendix III

METHODS OF STAPLE-LENGTH DETERMINATION IN COTTON USED AT DIFFERENT PLANT-BREEDING STATIONS IN INDIA

The existence of a high correlation between staple-length and spinning value [Turner and Venkataraman, 1933] makes the former a very useful estimate of quality in cotton. In order to compare methods of staple-length measurement current at different plant-breeding stations in India, two samples of cotton, one *desi* (Malvi 9) and another Upland (Dhar-Cambodia), were sent to the cotton research officers at several stations, with instructions to make twenty-five determinations on each sample by their own method. Replies were received from Lyallpur, Cawnpore, Sakrand, Viramgam, Surat, Jalgaon, Dharwar, Indore, Baroda, Nagpur, Parbhani and Coimbatore. The samples were also sent to the Director, Technological Laboratory, for determination of staple-length by Balls and Baer sorters. Data on mean values, standard errors and standard errors per cent of the means, and the percentage excess in staple-length of the Upland over the *desi* are given in Table I.

According to the method followed the stations can be divided into three groups :

(1) Surat ; measurement on samples of lint, as is done by graders.

(2) Sakrand and Viramgam ; measurement on either side of the seed, the halo being combed out like the wings of a butterfly. The average of the two readings is recorded as the measurement per seed.

(3) The remaining stations, one or more readings on the full halo combed out in a circular shape. Only one measurement per seed, the maximum halo-length, is taken at Indore, Baroda and Jalgaon. Bailey's celluloid protractor is used at Indore and Baroda and a pair of dividers at Jalgaon. At Cawnpore the halo is mounted on a black surface with horizontal lines five millimeters apart and the length to which the majority of fibres extends is recorded. The Dharwar measurements are described as those of the 'middle' fibres of each halo, taken probably with a pair of dividers. At Coimbatore a pair of dividers was used for measuring the maximum halo-length up to 1936, while Bailey's method [1930] has been adopted since then. Results obtained by both the methods are included in Table I.

TABLE I

Mean values and standard errors of staple-length measurements of desi *and Upland cotton by different methods*

Station	*Desi* (Malvi 9)			Upland (Dhar-Cambodia)			Per cent excess of Upland over *desi* in staple-length
	Mean staple-length (mm.)	Standard error of mean	Standard error per cent of mean	Mean staple-length (mm.)	Standard error of mean	Standard error per cent of mean	
Lyallpur . .	21·36	0·35	1·66	23·52	0·46	1·98	10·1
Cawnpore . .	17·04	0·36	2·13	20·00	0·35	1·78	17·4
Sakrand . .	18·20	0·23	1·28	21·12	0·34	1·61	16·0

TABLE I—*contd.*

Station	*Desi* (Malvi 9)			Upland (Dhar-Cambodia)			Per cent excess of Upland over *desi* in staple-length
	Mean staple-length (mm.)	Standard error of mean	Standard error per cent of mean	Mean staple-length (mm.)	Standard error of mean	Standard error per cent of mean	
Viramgam	19·88	0·34	1·72	22·07	0·31	1·42	11·0
Surat	20·16	0·11	0·57	21·88	0·13	0·61	8·5
Jalgaon	17·84	0·18	1·01	19·96	0·28	1·43	11·9
Dharwar	19·30	0·30	1·57	21·12	0·60	2·85	9·4
Indore	25·64	6·32	1·25	28·64	0·36	1·26	11·7
Baroda	21·68	0·20	0·95	23·88	0·25	1·06	10·1
Nagpur	19·63	0·29	1·49	19·75	0·34	1·75	0·6
Parbhani	17·36	0·19	1·07	18·83	0·31	1·64	8·5
Coimbatore (old method).	23·04	0·30	1·31	26·24	0·54	2·08	13·9
Coimbatore (new method).	22·40	0·35	1·55	24·16	0·63	2·61	7·8
Tech. Laboratory (Average of Balls and Baer sorter).	19·81	..	..	21·55	..	..	8·8

At Lyallpur, Nagpur and Parbhani readings are taken at more than one point on each halo and an average value per seed calculated. At Lyallpur, the average is obtained from three readings along the central radial lines on Bailey's disc. At Nagpur, readings are taken at eight equally spaced points on the halo by means of a transparent disc marked with concentric circles one-eighth inch apart, these readings being then averaged. The Parbhani method approaches Bailey's method more closely. Special discs are used, having six radial lines instead of five as on Baily's disc. Four measurements are taken along the four central radial lines and the fifth is the average of two measurements along the basal radial lines which are inclined to the horizontal, unlike those on Bailey's disc. These five readings are then averaged.

Selection of seeds for measurement relative to their position in the lock was not possible in the present material which was thoroughly mixed before drawing samples. Such selection is, however, practised at some stations. At Lyallpur sub-basal seeds from normal disease-free locks are taken for the purpose. At Coimbatore and Viramgam centrally situated seeds are chosen.

It will be seen that there is a considerable diversity in the technique of staple-length measurement from province to province, and even within the same province. Similar conditions appear to exist in other countries also. As early as 1930, Bailey advocated uniformity of methods among all research workers of the Empire Cotton Growing Corporation. It is not known what action was taken on his suggestion.

A comparison of standard errors per cent from Table I shows the relative efficiency of the different methods. These errors range from 0·57 to 2·85 per cent. Dividing the range into sections of 0·5 per cent each, the following distribution of the stations according to their standard errors is obtained.

Sample	Standard errors per cent				
	0·5—1·0	1·0—1·5	1·5—2·0	2·0—2·5	2·5—3·0
Desi	Surat Baroda	Jalgaon Parbhani Indore Sakrand Coimbatore (old) Nagpur	Coimbatore (new) Dharwar Lyallpur Viramgam	Cawnpore	..
Upland	Surat	Baroda Indore Viramgam Jalgaon	Sakrand Parbhani Cawnpore Nagpur Lyallpur	Coimbatore (old)	Coimbatore (new) Dharwar

The standard errors range between one and two per cent at the majority of stations. The somewhat high error at Cawnpore is partly due to the use of a crude unit of five millimeters. It is not clear why errors are high at Coimbatore and Dharwar. In comparing the efficiency of the different methods the number of readings taken must also be taken into account. For instance, though standard errors per cent for *desi* at Sakrand and Indore are nearly equal, fifty readings (two per seed) were necessary at Sakrand to give an accuracy equal to that attained at Indore with only twenty-five readings. The Nagpur method, which gives a somewhat higher standard error than Indore, must really be considered far more inefficient, in that the number of measurements taken at Nagpur is eight times that at Indore. Surat, Baroda, Jalgaon and Indore methods which with the minimum number of measurements give an equal or greater accuracy than other methods must, therefore, be considered more efficient than the latter.

Balls and Baer sorters used at the Technological Laboratory undoubtedly provide the best estimate of mean staple-length. Both methods are unfortunately very laborious and slow and are of limited value to the plant breeder who must examine a very large number of samples for staple-length each season. The methods used by plant breeders differ from the sorter method in one important respect. While the sorter takes into account hairs of all lengths, a large proportion of short hairs which are hidden under longer ones [Hilson, 1923 ; Hutchinson and Panse, 1935] are left out when a tuft of lint or a halo is measured by plant breeders' methods. No appropriate allowance can be made for these short hairs by taking more than one reading on each halo and by making some arbitrary correction as in Bailey's method. The labour of making extra measurements can, therefore, be safely avoided as far as they are meant for this purpose. Their relation to variability will be discussed later.

Since the measurements are restricted to the longer hairs that are visible, and are also taken from the centre of the seed, the plant breeders' estimates of staple-length are expected to be somewhat greater than those obtained by the use of the sorter, the amount of excess depending on the method of measurement. It is, therefore, surprising that mean values obtained at Cawnpore, Parbhani and Jalgaon both for *desi* and Upland samples are lower than the Technological value by amounts greater than twice their standard errors. Sakrand belongs to the same group, except that the value for the Upland sample there is lower than the Technological value by a smaller amount. Some factor in the method of measurement is responsible for these seriously low values. Values at Dharwar, Nagpur (*desi*), Viramgam and Surat do not show appreciable differences from the Technological values while those at the remaining stations are greater by more than twice their standard errors. The mean values obtained at Indore are the highest. The measurement made is strictly that of the maximum halo-length. Readings are taken on the longest bunch of hairs on the seed forming a visible edge, stray long hairs being excluded. It should be noted that the Indore values are significantly greater than those at Baroda and Jalgaon, though at the all three stations maximum halo-length is apparently measured.

Selection of seed located at a certain point in the lock is not desirable. Hilson [1923] has shown that there is no difference in the halo-length of different seeds in the same lock. If, on the other hand, there was a difference the halo-length obtained would be characteristic of the selected seed and not of the whole sample. Since the object of halo-length measurement is to secure values representative of the sample, selection within the sample must be avoided and the seed for measurement taken strictly at random. This would also eliminate a considerable amount of labour necessary for preserving the locks intact and sampling them carefully. Seed-cotton is picked at Indore by pulling it away from the plant and in cotton with loose locks distinction between locks is not possible at the time of staple-length measurement. If the sample is disease-attacked, disease-free normal seeds may be selected when the object is to measure staple-length of normal cotton only.

A millimeter is the unit used for staple-length measurement at the majority of stations. At Cawnpore it is five millimeters and at Nagpur it is a little over three millimeters, actually one-eighth of an inch. The use of a crude unit introduces greater variability and may also cause some bias in the measurement. If the halo ends between two divisions, there will be a tendency to read whole numbers in preference to fractions, and there is a likelihood of a bias towards higher or lower numbers resulting in an over-estimate or an under-estimate of the mean. The frequency distribution of two hundred readings (eight per seed) at Nagpur on the Upland sample is given below and illustrates the preference for whole numbers over fractions.

Divisions (1 div. = 1/8 in.)

4	4·5	5	5·3	5·5	6	6·5	7	7·5	8
3	..	35	1	14	57	19	54	9	8

It has been shown above that taking several readings on one seed in order to obtain an average more nearly corresponding to mean hair-length is not of any use. Their value in reducing variability between seeds will depend upon what proportion of the total variation between seeds is represented by variation within the seed. This was studied on Sakrand and Viramgam data in which measurements on two sides of each seed are given and on Nagpur and Parbhani data in which eight and six readings per seed respectively are recorded. Below are given the analyses of variance of these data.

Due to	Degrees of freedom	Viramgam		Sakrand	
		Mean sq. *desi*	Mean sq. Upland	Mean sq. *desi*	Mean sq. Upland
Between seeds . . .	24	5·83	4·89	2·71	5·76
Within seeds . . .	25	0·28	0·35	0·60	0·67

At Viramgam variation between the two sides of the seed accounts for only 4·8 and 7·2 per cent of the total variation between seeds in the *desi* and Upland samples respectively. The corresponding values at Sakrand are 22·1 and 11·6 per cent. It should be noted that the variation between the two sides of the seed at Sakrand is nearly twice that at Viramgam without any corresponding increase in the variation between seeds. This is responsible for the higher percentages at Sakrand. Hilson [1923] states that there is no difference between the two sides of the same seed.

Due to	Parbhani			Nagpur		
	Degrees of freedom	Mean square *desi*	Mean sq. Upland	Degrees of freedom	Mean square *desi*	Mean sq. Upland
Between seeds	24	5·37	13·79	24	17·13	23·88
Within seeds	125	0·83	0·73	175	3·05	5·49

The variation within seeds is 15·5 and 5·3 per cent of the total variation between seeds for *desi* and Upland samples respectively at Parbhani, the corresponding values at Nagpur being 17·8 and 23·0 per cent. Figures for variance both between and within seeds at Nagpur are strikingly higher than at any other centre, apparently due to the use of a crude unit.

It will be seen that the variation between different readings on the same seed is small compared to the total variation between seeds, its highest proportion in the data examined being 23 per cent. This means that nearly four-fifths of the variance or more between seeds is independent of that within seeds and cannot be affected by the number of measurements per seed. If variation between plants in a progeny and variation between plots in a replicated trial is also taken into consideration, variation within seeds becomes a negligible fraction of the total variation affecting staple-length measurement, since it has been shown [Hutchinson and Panse, 1935] that variation due to soil heterogeneity is very large compared to other factors.

At a given station the absolute magnitude of mean values obtained by the method followed is of little importance in judging the usefulness of the method in testing quality as far as it is reflected in staple-length. The real criterion is the magnitude of correlation between staple-length and spinning value. Wherever data are available they should be examined to study this correlation. Mean fibre-length obtained by the sorter method is known to be closely correlated to spinning value [Hutchinson and Panse, 1935] and from the last column in Table I it will be seen that the Upland sample has 8·8 per cent longer staple than the *desi* sample when tested by this method. As far as can be judged from these two samples, methods that show a similar differentiation between them in staple-length are likely to give a better indication of their relative spinning value than those in which the relationship between the two samples is different. At Cawnpore and Sakrand and also at Coimbatore with the old method, the percentage excess of Upland over *desi* is considerably greater than the Technological Laboratory value. On the other hand there is practically no difference between the two samples at Nagpur. Figures for the remaining stations show a much better agreement with the Technological value.

It is possible to study directly the correlation between staple-length as measured by the Indore method and spinning value, from data accumulated over a period of six years Samples of lint of selected strains and local cotton both *desi* (*G. arboreum*) and Upland (*G. hirsutum*) grown in Central India are annually sent to the Technological Laboratory for fibre and spinning tests. Halo-length measurements on seed-cotton before ginning are also available for several samples from the year 1931-32 to 1936-37. From these data various correlation coefficients were calculated for *desi* and Upland samples separately and are given below. The number of pairs from which each coefficient was obtained is given in brackets and the significance of the coefficient is indicated at two levels of P, 0·05 and 0·01.

Sample	Correlation coefficient between				
	Balls sorter and halo-length	Halo-length and spinning value	Balls sorter and spinning value	Balls sorter and grader's estimate	Grader's estimate and spinning value
Desi . .	0·59**(58)	0·72**(49)	0·63**(79)	0·25*(79)	0·12(79)
Upland . .	0·60**(30)	0·52* (16)	0·49* (17)	0·58*(17)	0·01(17)

*Significant for $P = 0·05$; **Significant for $P = 0·01$.

There is a significant correlation of 0·6 between halo-length and Balls sorter both for *desi* and Upland samples. Fibre-lengths obtained by the two methods are also almost equally correlated with spinning value. Taking Balls sorter as the standard, the halo-length measurement therefore seems to provide an equally efficient method for judging the spinning quality of cotton samples.

It is interesting to note that the grader's estimate shows a significantly poorer correlation with Balls sorter than the halo-length does in *desi* samples, while in the Upland group both are equally correlated with Balls sorter. With spinning value the grader's estimate shows no correlation at all. Bailey [1930] refers to the poor correspondence between halo-length and the grader's estimate. The present results support his findings, and suggest some defect in the grader's estimate as the likely cause. Data from Surat (Table I) are obtained by this method and, while the standard errors are low and mean values closely related to those obtained at the Technological Laboratory, the relationship between staple-lengths determined by this method and spinning value might be examined from past records at the station before continuing its use extensively for routine measurement. It is possible that the method differs in important details from the grader's method and is worthy of a critical examination.

It should be noted that the correlation coefficients discussed above were calculated from data restricted to samples belonging to the two species, *G. arboreum* and *G. hirsutum* grown in Central India. Examination of material from other parts of India should provide valuable information for verifying the conclusions drawn here.

It is clear that the most suitable method for staple-length measurement should show the highest possible correlation with spinning value, should be sufficiently accurate, quick and simple. Such a method will enable a large number of samples to be examined each season by the usual staff at a plant-breeding station and the plant breeder can use it with advantage to obtain reliable estimates of spinning quality in his material, as far as this quality depends on staple-length. If a uniform method is adopted at all plant-breeding stations in India, it will make possible a comparison of staple-length values obtained at different stations and greatly facilitate exchange of material and data.

The Indore method which embodies all the requirements of a suitable method may be recommended for a trial and for comparison with the local method at all plant-breeding stations. Its working details are recapitulated below :

The seed is selected strictly at random from the sample to be examined. Combing is done as recommended by Bailey [1930], but with weavers' steel combs, by boys and girls trained for the purpose. The halo is mounted on velvet-covered wooden boards with the butt end of the seed away from the observer and the hairs are gently smoothened out, those detached from the seed being removed during the process. Measuring is done with Bailey's celluloid protractor arranged over the halo with the butt end of the seed flush with the upper edge of the hole in the protractor without attempting to press it down too firmly over the seed. While isolated long fibres are excluded, a bunch of the longest fibres producing a clearly visible edge is measured. Only one such reading per seed is possible. Five random seeds per plant are taken for measurement.

Bailey's disc is more convenient than a pair of dividers enabling the edge of the halo rather than ends of individual fibres being measured and also on account of quickness and ease of reading against the millimeter graduations on the disc.

The maximum halo-length is a single definite measurement per seed and does not allow much subjective interference on the part of the observer.

REFERENCES

Bailey, M. A. (1930). *Report and Summary of Proc., E. C. G. C. Conference on Cotton Growing Problems, p.* 152

Hilson, G. R. (1923). *Agric. Res. Inst. Pusa Bull. No.* **138**

Hutchinson, J. B. and Panse, V. G. (1935). *Ind. J. Agric. Sci.* **5**, **545**

Turner, A. J. and Venkataraman, V. (1933). *I. C. C. C. Tech. Lab. Bull. (Ser. B)* **17**

Appendix IV

SPECIMEN SCHEDULE GIVING DESCRIPTIONS OF MALVI 9 AND FIVE SUB-STRAINS

(a) *General*

1. Station—Institute of Plant Industry, Indore, Central India.

2. Year—1936-37.

3. Nature of the soil—Black cotton.

4. Amount of rainfall—Total 32·02 in. in 1936.

5. Temperature range—Max. Min.

6. Humidity range—

7. Dates of incidence of frost—34°F. on 28th December 1936 ; 32°F. on 6th January 1937.

8. Nature and rate of manure applied—Unmanured.

9. Date of sowing—24th June 1936.

10. Seed rate—20 lbs. per acre.

11. Average spacing—Between rows 14 in. ; between plants 10 in. to 12 in.

12. Number of irrigations with intervals—Not irrigated.

13. Layout—Six randomised blocks, plot size 11 ft. 8 in. × 47 ft. = 1/79 acre.

(b) Plant and boll characters

Strain		Plant characters												Boll characters					
Old name	New name	No. of monopodials	Node No.	Frequency distribution of node numbers	Plant height (cm.)	No. of internode on main stem	No. of fruiting nodes	Shedding percentage	Stem-tip hairiness	Stem pigmentation	Leaf shape	Leaf and extra flora] nectaries	Corolla colour	No. of loculi per boll	Length and breadth of mature boll	Nature of boll face	Type of opening	Weight of *kapas* per 100 bolls	Remarks.
Malvi 9 * .	Indore 4 .	0·33	8·4		75		31·9	39·3	...	...	...	...	...	...	...	...	...	...	...
M9-13 .	Indore 5 .	0·72	8·7		70		36·0	35·7	...	...	...	...	...	...	...	...	...	...	...
M9-15 .	Indore 6 .	0·67	8·9		71		36·6	35·0	...	...	...	...	...	...	...	...	...	...	...
M9-17 .	Indore 7 .	0·68	9·5		72		30·8	37·9	...	...	...	...	...	...	...	...	...	...	...
M9-19 .	Indore 8 .	0·53	8·2		73		37·3	40·7	...	...	...	...	...	...	...	...	...	...	...
M9-20 .	Indore 9 .	0·58	8·4		74		37·6	40·4	...	...	...	...	...	...	...	...	...	...	...
Standard error	...	0·40	0·14		2·8		3·2	2·3	...	...	...	...	...	...	...	...	...	...	...
Significant difference	...	...	0·4		...		...	...	...	...	...	...	...	...	...	...	...	...	...

* This Standard. In fifteen replicated varietal trials from 1932-33 to 1935-36 at six centres in Malwa, Malvi 9 gave an average 22 per cent higher yield of seed cotton, 8·8 per cent longer staple and 11 per cent higher ginning percentage than the local cotton.

(c) Yield and maturity, seed-cotton and lint characters

Strain		Yield and maturity				Seed-cotton characters								Lint characters											Remarks.
Old name	New name	Yield of seed-cotton lbs. per acre	Maturity percentage yield up to		Picking period	Lint colour	Maximum halo-length (mm.)	Ginning percentage	Weight of 100 seeds.	Lint index	Tenacity of lint on seed	Fuzziness of seed	Colour of fuzz	Colour		Feel	Hair length (inches)	Hair weight 10⁻⁶ oz.	Maturity percentage of hair			Spinning value H.S.W.C.	Evenness class of yarns	Neps per yard of yarn	
			1-12-36	15-1-37										a	b				Mature	Half mature	Immature				
Malvi 9*	Indore 4	503	56·0	Crop killed by frost on 6th January 1937	23-11-36 to 4-1-37		24·6	32·5						White			0·79	0·205				15	4	1·8	
M9-13	Indore 5	383	51·5				25·0	32·9						White			0·805	0·191				16	4	2·5	
M9-15	Indore 6	417	50·3				24·5	33·5						White somewhat stained.			0·80	0·191				17	4	2·5	
M9-17	Indore 7	381	45·0				25·9	34·6						White			0·785	0·201				17	3	2·2	
M9-19	Indore 8	458	43·9				25·0	32·0						White slightly stained and dull.			0·785	0·205				17	4	1·2	
M9-20	Indore 9	486	49·7				25·2	33·3						Do.			0·825	0·173				16	3	1·5	
Standard error	...	265	...				0·4	0·2																	
Sig. diff.	...	77	...					0·5																	

*This Refer to note under (*b*).

II. VARIABILITY IN RICE

(Received for publication on 20th May 1938)

(With Plates XXXVIII-LIII)

ORIGIN AND CLASSIFICATION

ORYZA, the genus to which cultivated rice belongs, is a native of the tropics of both hemispheres, growing in wet places, the important species being *O. sativa*, comprising several distinct races and varieties of rice. All the cultivated forms of rice whether in Italy, Japan, America or India belong to this single species *O. sativa*. *O. glaberrima* is next in importance and includes a few varieties of cultivated rice grown specially in Africa. A thorough and comprehensive botanico-geographical survey of the genus, particularly in India and the eastern countries, has not been made and the available information regarding species and their distribution is still meagre. Cyto-taxonomic studies combined with cytogenetic investigations, which in modern times have been of great aid for the elucidation of phylogenetic development, have not proceeded far enough in respect to this genus. There exists, therefore, a considerable amount of confusion with regard to the proper classification of the species. Sometimes the same species is designated by different names, as for example, *O. barthii* and *O. longistaminata*, or two different species are called by the same name, as for example, *O. latifolia* and *O. officinalis*. Even the present designated species have to be examined whether they deserve a species status. *O. glaberrima* which is largely cultivated in Africa is very similar in morphological characters to *O. sativa* and it crosses readily with the latter showing ordinary Mendelian segregation of its characters in the progeny. The glabrous nature of the glume, on which the specific difference between the two species is based, has itself been found to follow a multiple factor segregation in crosses studied at the Paddy Breeding Station, Coimbatore. It would, therefore, appear that it is only a variety of *O. sativa*. The position of certain other species, for example *O. stapfii*, *O. grandiglumis*, has got to be examined from this point of view. Hence, a more comprehensive and systematic study of the genus in all its aspects is called for before a thorough understanding of the problem of its origin and evolution is possible.

The two main contributions to the systematics and distribution of *Oryza* species are from Roschevicz [1931] and Chevalier [1932]. About twenty-five species in the wild state are known to be distributed over India, Africa, Philippines, Java, South and Central America and islands lying close to it. Both the authors divide the genus into four sections, although the species included by them in the various sections are not the same. According to Roschevicz the first section, consists of twelve species including *O. sativa* L. *spontanea*=*O. sativa fatua* (Chevalier) which is widely spread covering the entire range of distribution of the genus. He believes that *O. sativa* L. *spontanea* of this section, which occurs in Asia, Indo-China and North Australia, in places of most ancient and intensive rice cultivation, is the progenitor of most of the cultivated rices in India and Indo-China, because of its resemblance to cultivated forms. He also believes that *O. breviligulata*, another member of this section, should have given rise to African cultivated rices and *O. minuta*, a third member, to small-fruited cultivated rices and *O. officinalis*, still another member, to some of the Asiatic rices. He thinks that wild species belonging to the other sections of the genus have had no part in the origin of cultivated rices. Although it is quite likely that *O. sativa* L. *spontanea* has played an important role in the origin of cultivated rices, there is not enough evidence to preclude altogether the possibility of other wild rices being responsible for the origin of cultivated rices. His contention that *O. minuta* should have been the progenitor of small-fruited forms does not seem to be valid for the reason that recent cytological findings [Ramanujam, 1938] do not support such a conclusion. *O. minuta* has $2n=48$ chromosomes while all the small-fruited cultivated sativas so far examined have only $2n=24$. It is, therefore, probable that *O. minuta* is a younger species having resulted from interspecific hybridisation followed by chromosome doubling. There are also a few other tetraploid species like *O. cubensis* and *O. latifolia* [Gotoh and Okura, 1933] and *O. coarctata* (unpublished results) each of which has 48 somatic chromosomes. All these species might have presumably arisen through polyploidy. So far, the chromosome numbers of only a few species of *Oryza* are known [Ramanujam, 1938]. Until we have made a thorough investigation of the chromosome numbers of all the *Oryza* species and examined their relationship by interspecific crosses, any interpretation of phylogeny of the genus must remain doubtful. Up to now only hybrids between *O. officinalis* × *O. sativa*, *O. longistaminata* × *O. sativa*, *O. sativa* × *O. minuta* and *O. latifolia* × *O. sativa* are known.

As regards the centre of origin of *Oryza* and more particularly the cultivated rice, *O. sativa*, opinion is more or less agreed on the latter while it is still a matter of speculation on the former. The historical and pre-historical evidence goes to show that the cultivation of rice in India and Indo-China is very ancient and it is in these countries that the greatest diversity of forms exists. Roschevicz believes that the cultivated rices arose first in Asia, namely in India and Indo-China, the conditions in those countries favouring mass mutations. He, however, thinks that the centre of origin of the section *sativa*, which includes *O. sativa* L. *spontanea*, the progenitor of the cultivated rices, is Africa as seven out of the twelve species in that section are found distributed in that area as against only three in Asia, and two in South and Central America. This conclusion of Roschevicz must remain tentative until a more thorough exploration of India and other eastern countries is made of the *Oryza* species. Work at Coimbatore (unpublished) has brought to light a new species not recognised before, and it is likely that a systematic survey of the wild species of India will reveal others, hitherto undiscovered species which may throw light on this problem. In this connection it may be stated that Flakesberger [1932] mentions that Vavilov, who took up the study of the whole world diversity of cultivated plants, has fixed upon south-west Asia as the centre of concentration of rice forms.

While the really wild species of *Oryza* do not cross with the cultivated rices, the form *O. sativa* L. *spontanea*, same as *O. sativa fatua*, crosses very freely with them. It occurs all over India and is the species most closely approaching the varieties of cultivated rice, differing from them only with respect to the ease with which the grains shatter from the panicle. Hybrids are known to produce fertile offsprings with various degrees of *spontanea* characters in them. Observations in Coimbatore have shown that while the percentage of natural crossing among cultivated rices may vary from 0 to 4, even under the most favourable circumstances, the percentage of natural crossing between *O. sativa* L. *spontanea* and cultivated rices may be as high as ten to fifteen. The occurrence of mutations has also been found to be much more common than was suspected, particularly in hybrid material. This along with natural crossing, both among the cultivated rices and between cultivated rices and *O. sativa* L. *spontanea*, might be said to account for the great varietal diversity in cultivated rices of India. Selective forces, both natural and human, have helped in the preservation of the most suitable forms for particular conditions of soil and climate.

On the analogy of the Russian botanists on various crops there can, however, exist different geographical races within the same species with identical chromosome numbers. These races might resemble each other in morphological characters but produce various degrees of sterility in the offspring when crossed. Sterility is here due to different genic make-up of the chromosome sets arising from accumulation of mutations and is governed by specific genes. Two such races are now recognised in rice, the *Japonica* and *Indica*.

MATERIAL TO BE DESCRIBED

In rice the material to be described consists of two kinds, one made up of strains evolved by the several departments of agriculture in India and which have attained commercial importance, and the other, type collections at each centre which serve as possible material for hybridisation or for exchange with breeders in other centres. While the former is likely to be small in number, the latter is likely to extend to several hundreds in each centre and possibly to several thousands for the whole of India. It is possible there might be duplicates in this latter group if morphological characters alone are taken into consideration, but it will be impossible to grow the whole of such a big collection at one centre and make a critical comparison of them with a view to eliminate duplicates. While the descriptions of types of commercial importance should be as elaborate and as detailed as possible, the description of the type collections will have to be simpler and should be considered mainly from the genetical point of view.

While in each province the collection of varieties can be reckoned in hundreds, it is obvious that all of them are not of great importance. Even in the most extensive rice-growing provinces like Bengal, Bihar, Burma and Madras the actual number of varieties that is grown extensively is not many. The number of varieties actually under cultivation is greater in provinces with greater diversity in the climatic and seasonal variations and hence in the rice-growing conditions. The collections are, in most cases, those isolated for small morphological differences, like colours at particular parts of the plant, and it is likely they will belong to the main variety or group from which they were first isolated in all essential physiological characteristics. These morphological differences are mainly of genetical interest and with the large range of variation in each of the characters and the large number of Mendelian genes involved, the number of possible combinations could be extended indefinitely and it can never be complete. It should, therefore, be enough to confine the descriptions to important varieties or groups of varieties recognised both by cultivators and in trade in the different provinces. This would help to keep the number to be dealt with within manageable limits.

Then again collections available with each breeder include, in several cases, some exotic (outside India) kinds introduced for trial and breeding. Such exotic types should be left out, except such of those as have been found to be economically useful. The general experience of most rice breeders in India has been that the exotic types have proved useless except very occasionally as parents in hybridization work.

The collections also include in some cases types or varieties obtained from other provinces for local trial. Since these are expected to be dealt with by the breeder in the particular province from which such types were introduced, they should also be dropped. If for any special reason, say its extreme popularity and usefulness in the new tract, the introduced type has to be dealt with, the original number and name of the type should be retained. For example, if Mysore State wants to include the description of GEB. 24 rice (a strain introduced from Madras) in its rice collections, it should still go by the number GEB. 24 and not with a new Mysore number.

CHARACTERS TO BE DESCRIBED

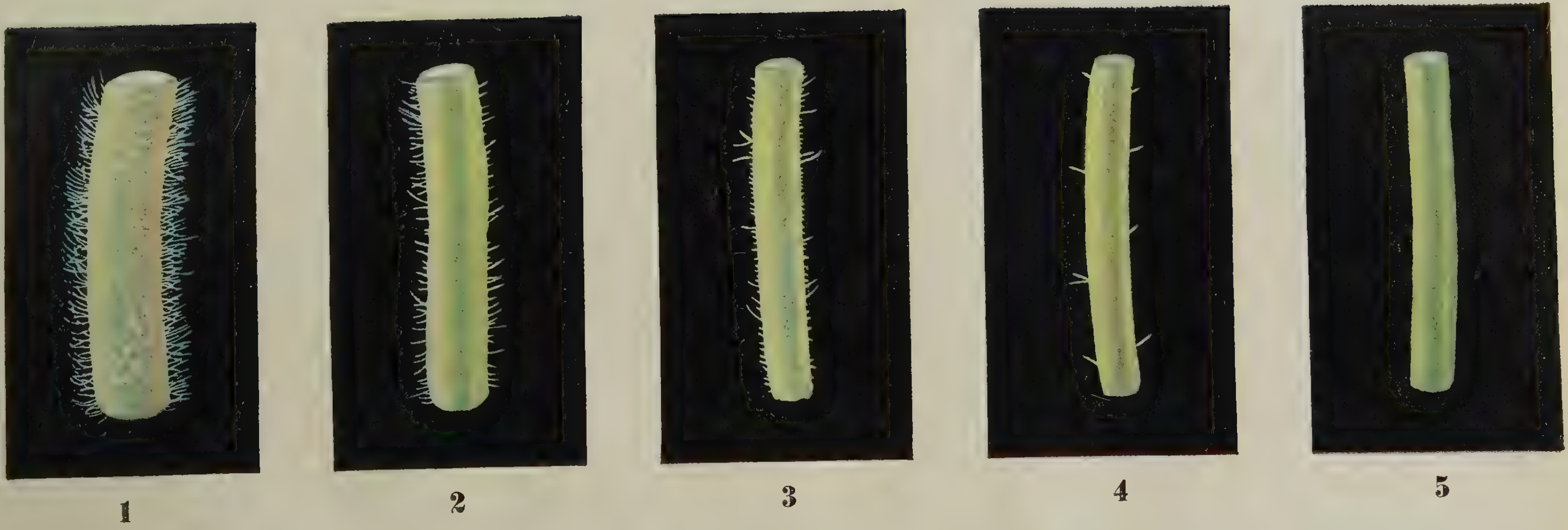
The characters to be described are of two kinds: (1) qualitative and (2) quantitative. The first one is practically little influenced by the environment in which the plant is grown and can be easily described. The colour characters come under this category and to facilitate dealing with them special notes (Appendix II) and coloured plates have been prepared. To aim at uniformity throughout India in the naming of the parts of the rice plant a sketch of the plant with the parts named has been included (Plate XXXVIII and Appendix I).

Even with regard to the quantitative characters which are subject to the influence of environment, some vary more than others. These are dealt with separately. The data on more variable quantitative characters, like yield, number of tillers, etc., are better collected from a properly laid replicated trial. Such data is likely to be available for the types that have been distributed to the cultivators after adequate trials. For varietal collections which are not usually grown in replicated plots the data can be given from an adequate sample taken out of the progeny rows, together with an estimate of the standard error. When the same varieties are grown in progeny rows over a series of years, it should be possible to treat the data from different years as replications and make a more valid estimate of the error involved.

GENERAL SCHEDULE PROPOSED FOR RICE

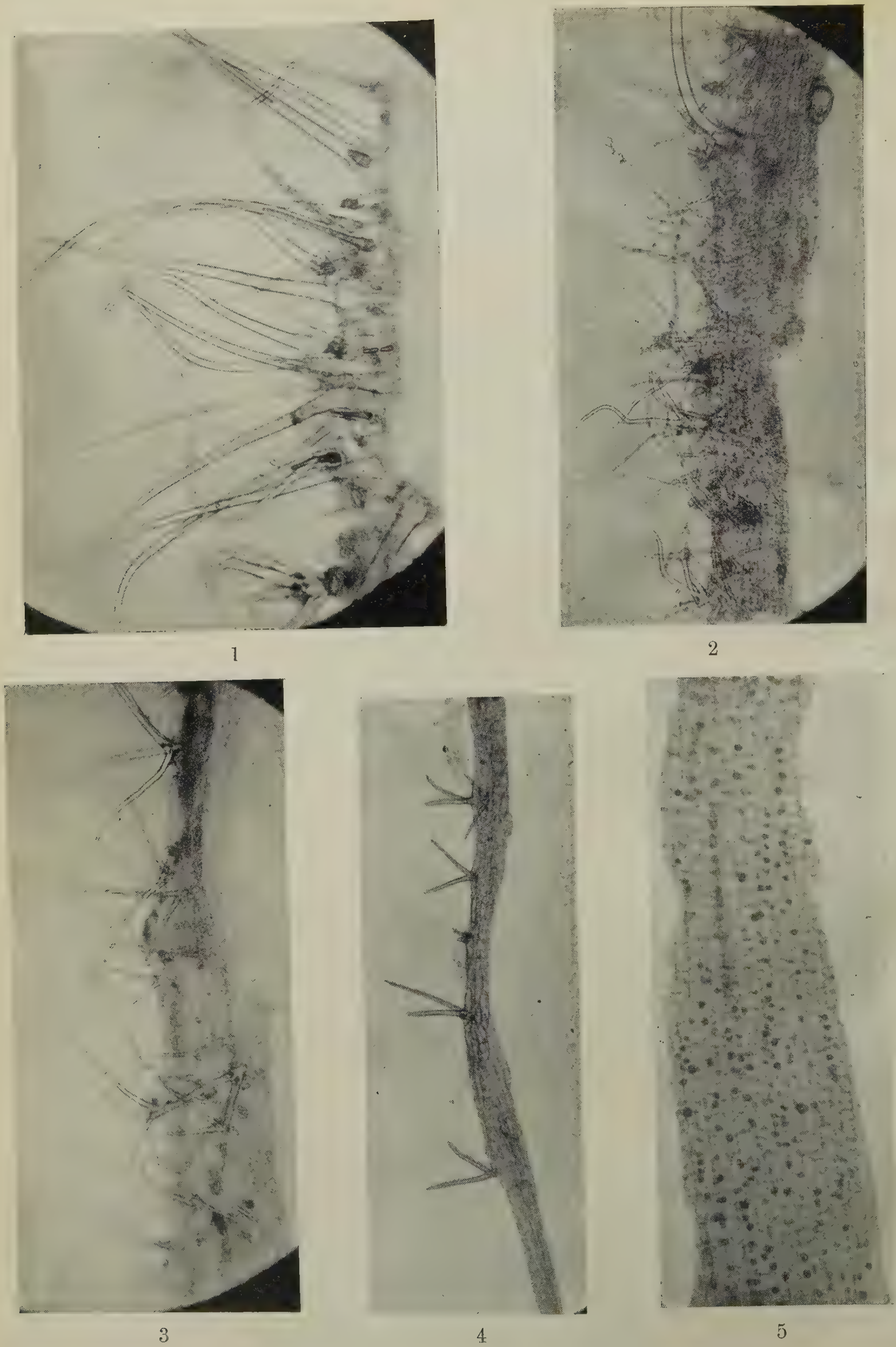
Experiment Station	Coimbatore, Karjat, Karimganj, Nagina, etc. Suitable contractions may be used—as for example Co for Coimbatore, Sknd for Sakrand, etc.
Type	Old name and number. New code letters and number, *e.g.*, Co 8, Adt 5. Origin—mention whether simple selection or hybrid, and in the latter case the parents involved.
1. *Group to which the rice belongs*	Autumn, winter, spring or summer rices. Since the grouping refers to the period of harvest the following convention shall be adopted :—
Autumn rices	Those harvested during August-October.
Winter rices	Those harvested during November-February.
Spring rices	Those harvested during mid March-mid May.
Summer rices	Those harvested during June-July.
2. *Method of sowing*	Seeded (broadcasted or drilled) or transplanted or both.
3. *Morphological characters*	Since the rice varieties are distinguished by the presence of anthocyanin pigmentation in the various parts of the plant, the presence or absence of pigment in the following parts may be indicated in a tabular form :—
Root	
Coleoptile or primary sheath	
Leaf sheath	Grade according to Plate XXXIX
Sheath axil	
Internode	Plate XL
Leaf juncture	
Auricle	
Ligule	
Pulvinus	
Septum	
Leaf blade	Plate XLI
Glumes	Also see inflorescence
Lemma and palea	Plates XLII—XLIV
Apiculus	Plate XLII
Stigma	
Awns	
4. *Habit*	Tillers prostrate (characteristic of wild rices only), spreading, erect, and floating habit.

PLATE XXVI



'Stem-tip' hairiness (Asiatic cottons)

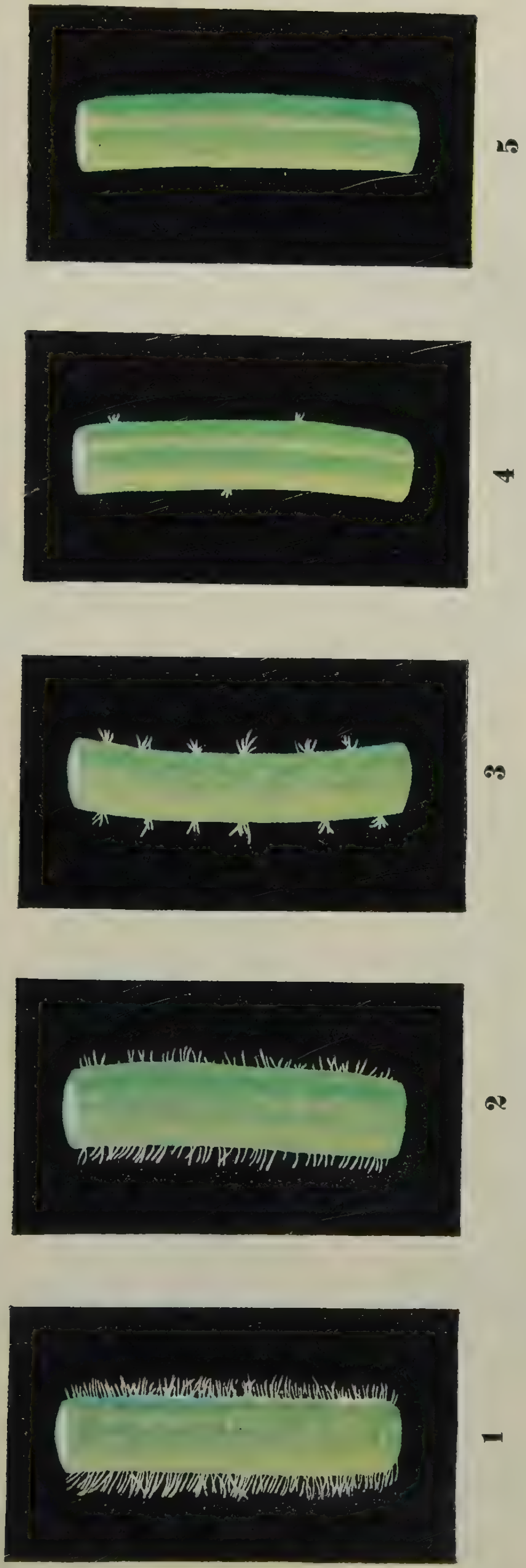
PLATE XXVII



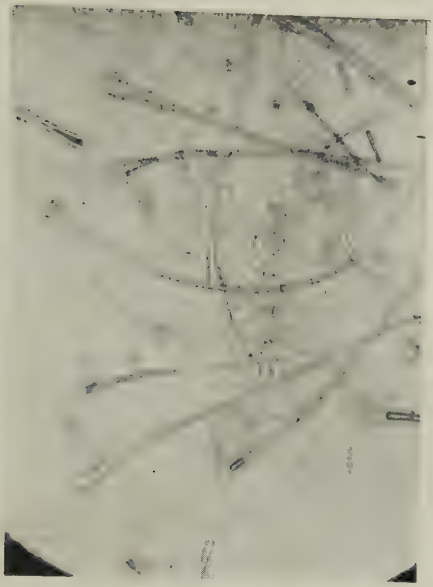
1 2 3 4 5

Longitudinal sections (×80) of corresponding grades in Plate XXVI

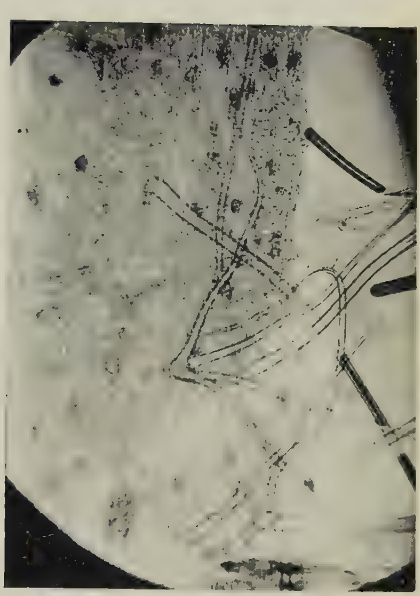
PLATE XXVIII



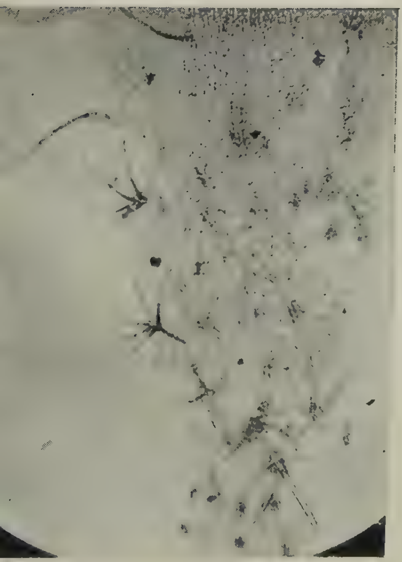
‘Stem-tip’ hairiness (American cottons)



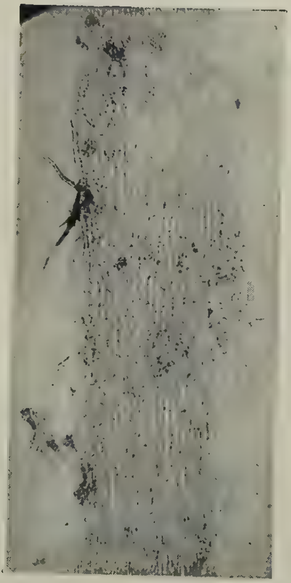
1



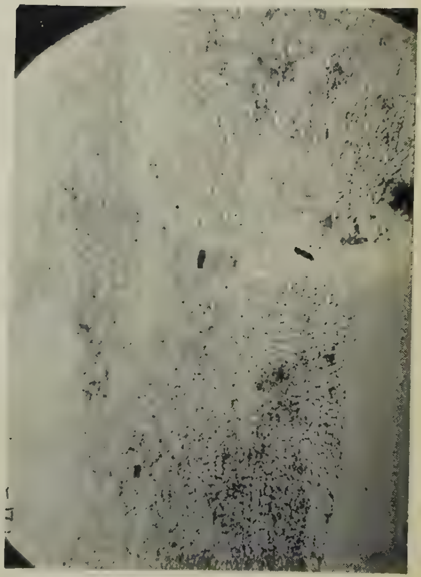
2



3



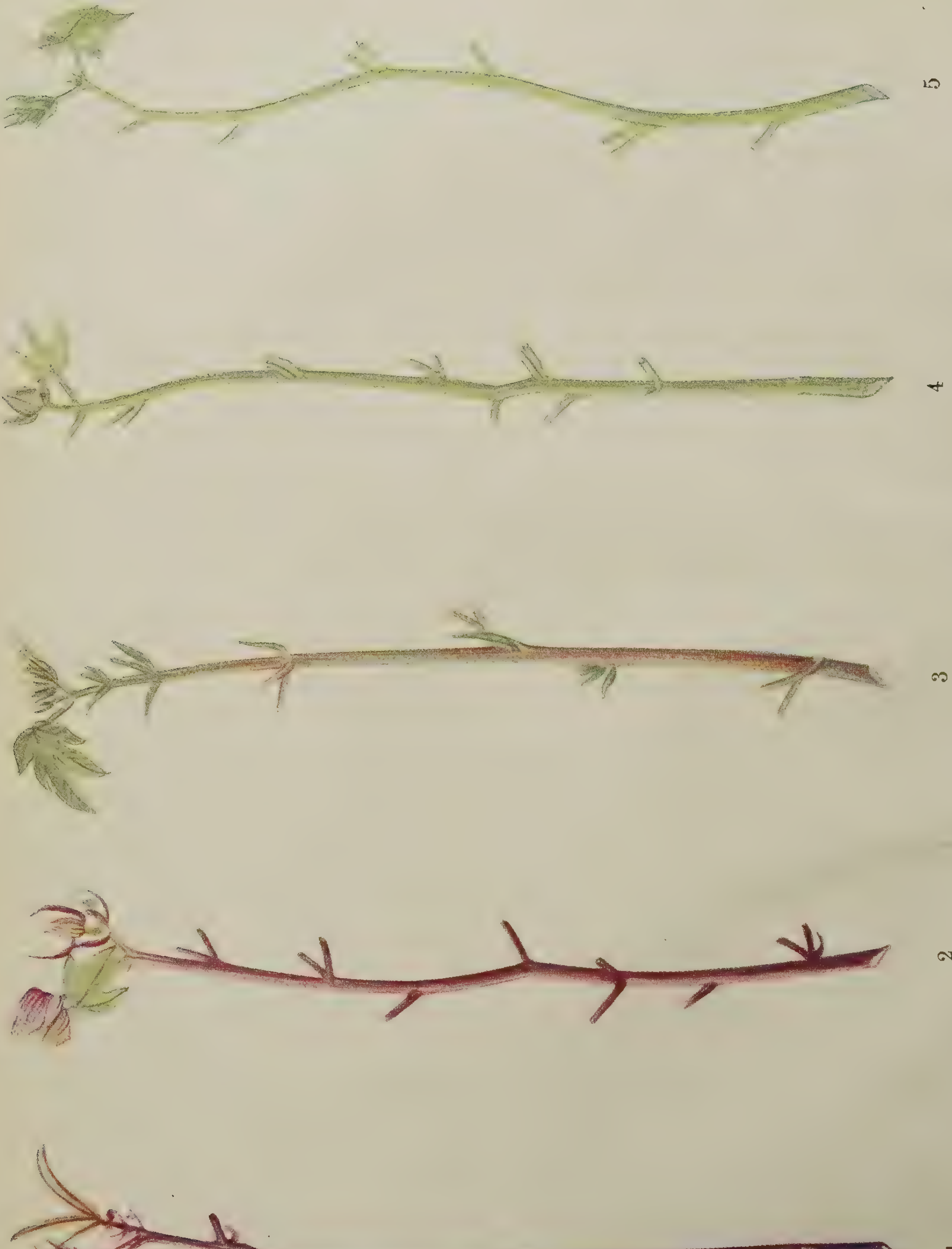
4



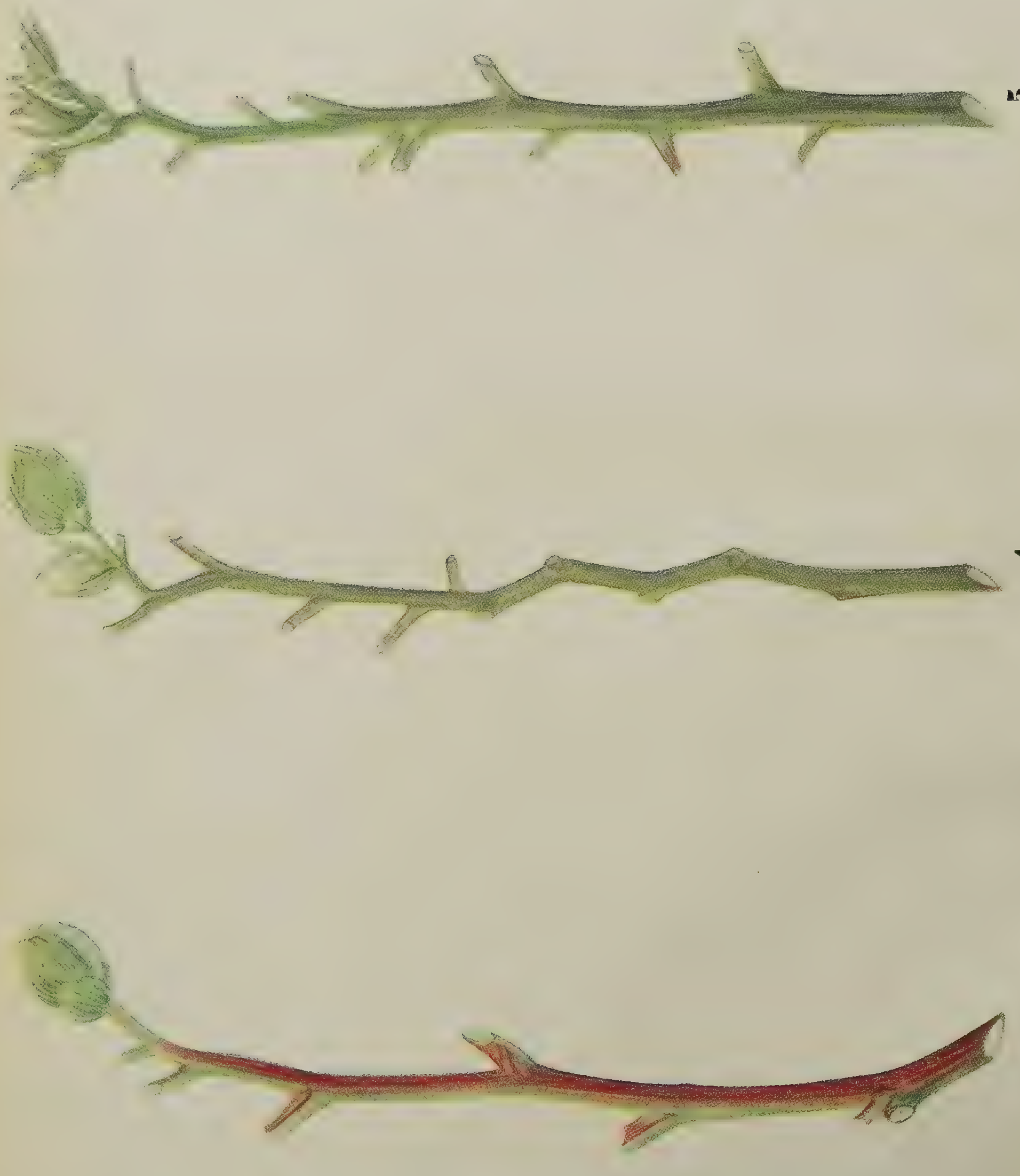
5

Longitudinal sections (×80) of corresponding grades in Plate XXVIII

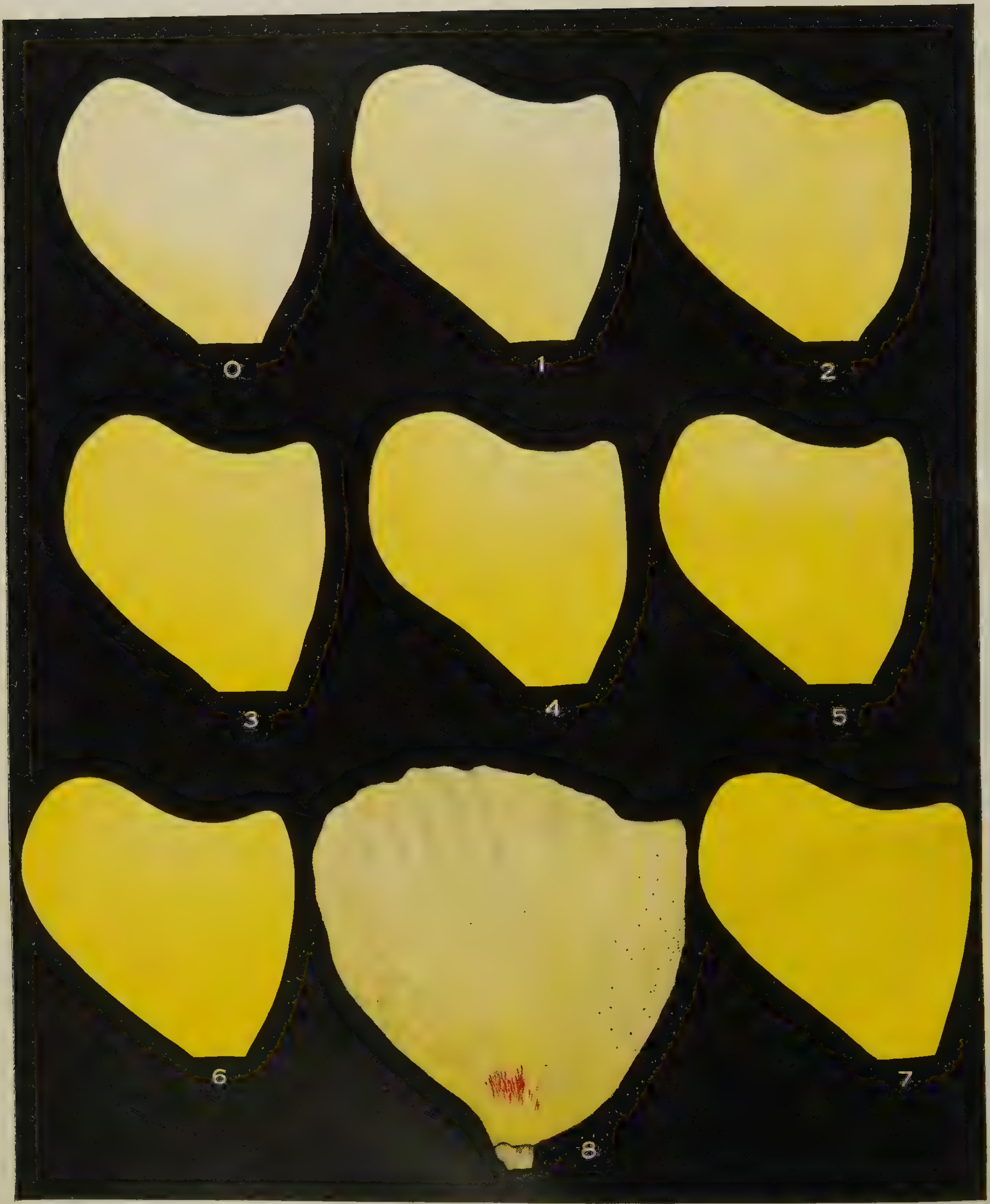
PLATE XXX



Stem colour (Asiatic cottons)

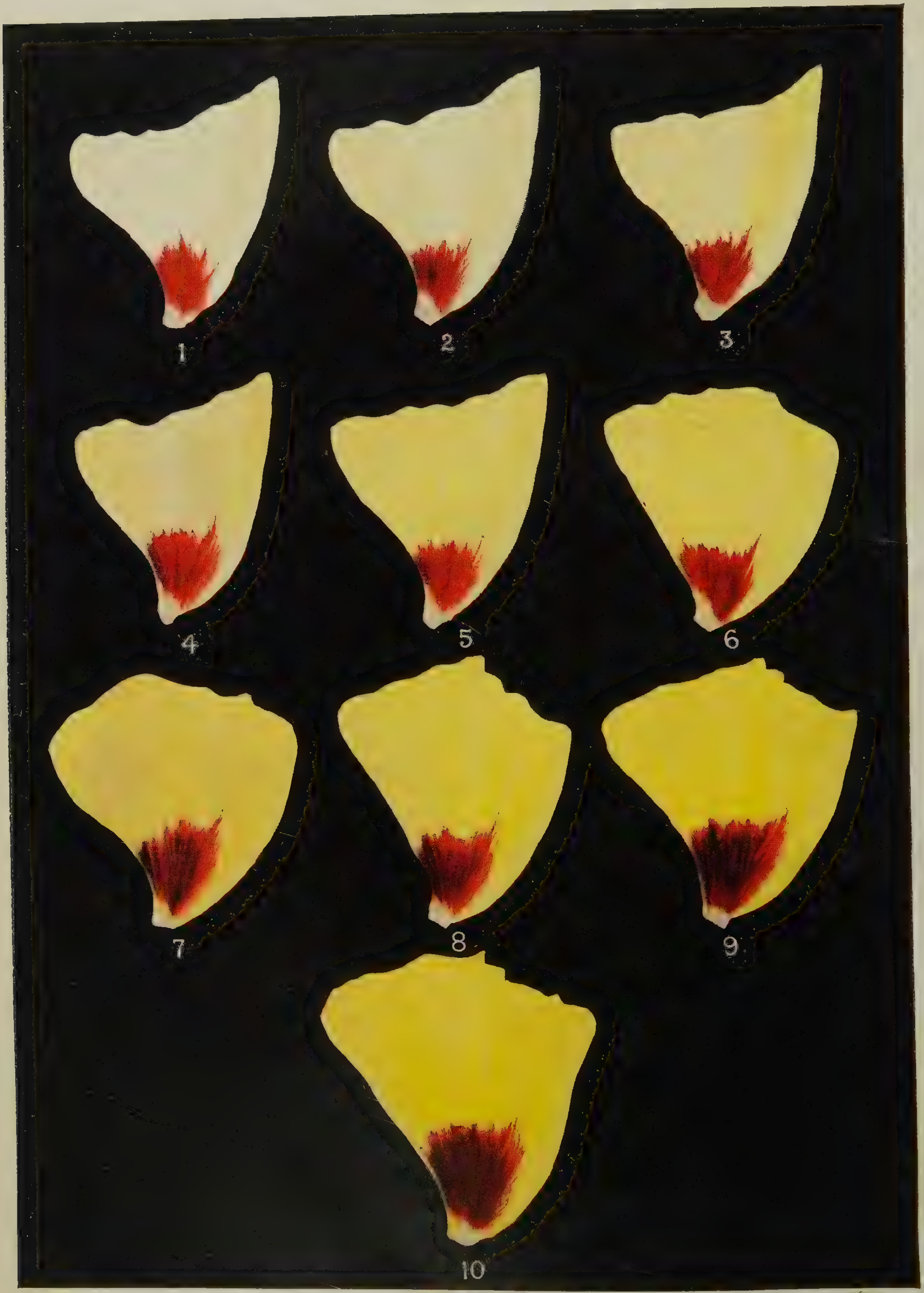


Stem colour (American cottons)



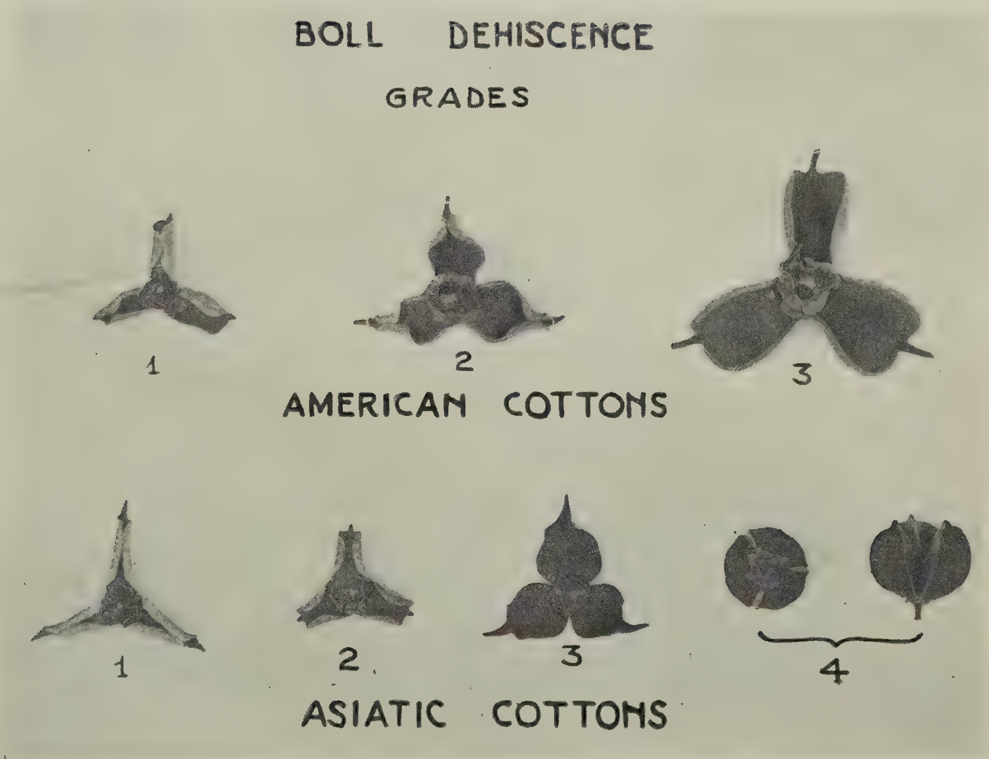
Reproduced with permission from the Journal of Genetics, *Vol. 21, No. 1*

Grades 0—7 of yellow in New World cotton. Fig. 8 shows a petal of sea Island white cotton



Reproduced with permission from the Journal of Genetics, *Vol. 24. No. 3*

Grades of corolla colour in Asiatic cotton


BOLL DEHISCENCE
GRADES
1
2
3
AMERICAN COTTONS
1
2
3
4
ASIATIC COTTONS

FUZZ GRADES

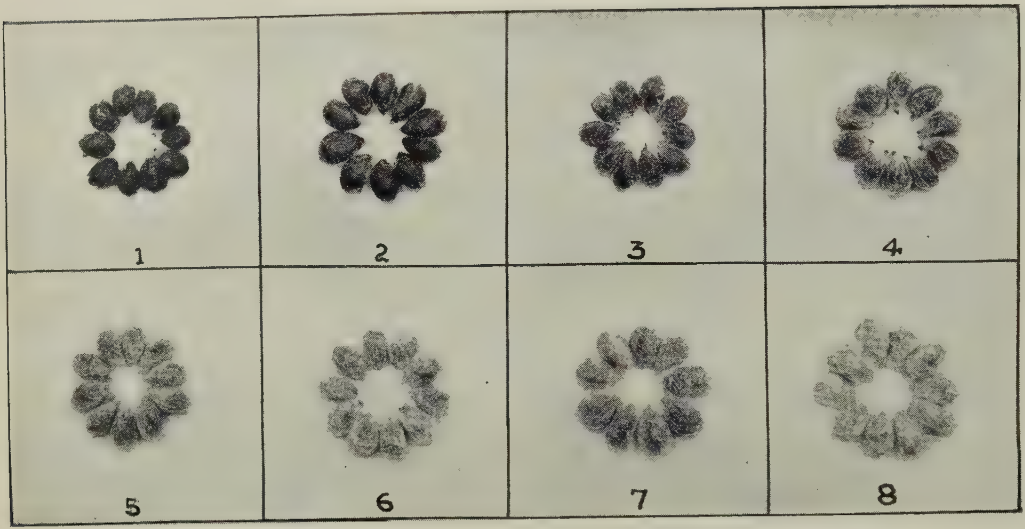


FIG. 1. Asiatic cottons

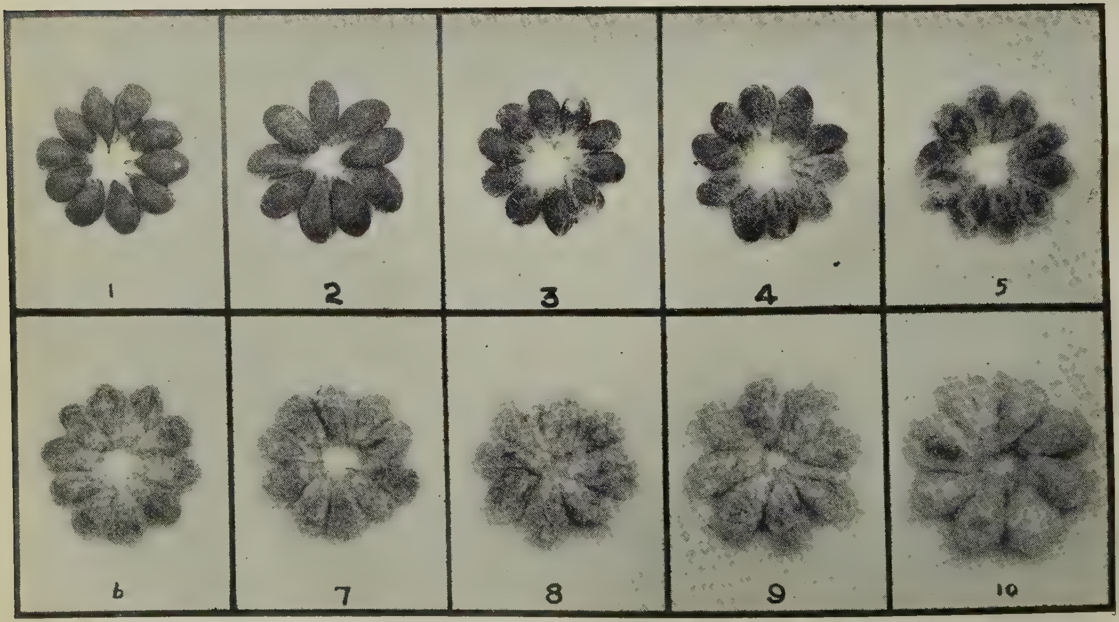

1
2
3
4
5
6
7
8
9
10

FIG. 2. American cottons

FUZZ COLOUR GRADES

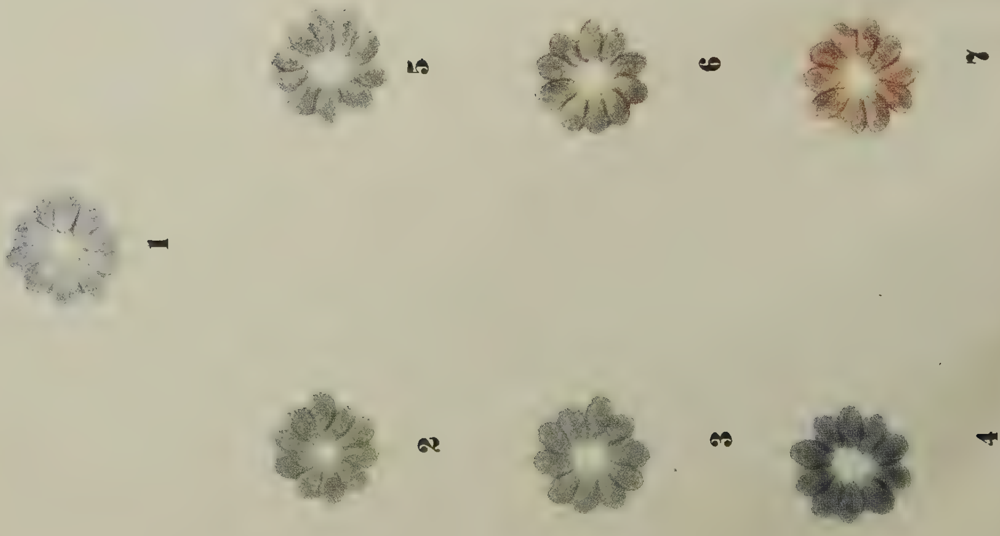


FIG. 1. Asiatic cottons

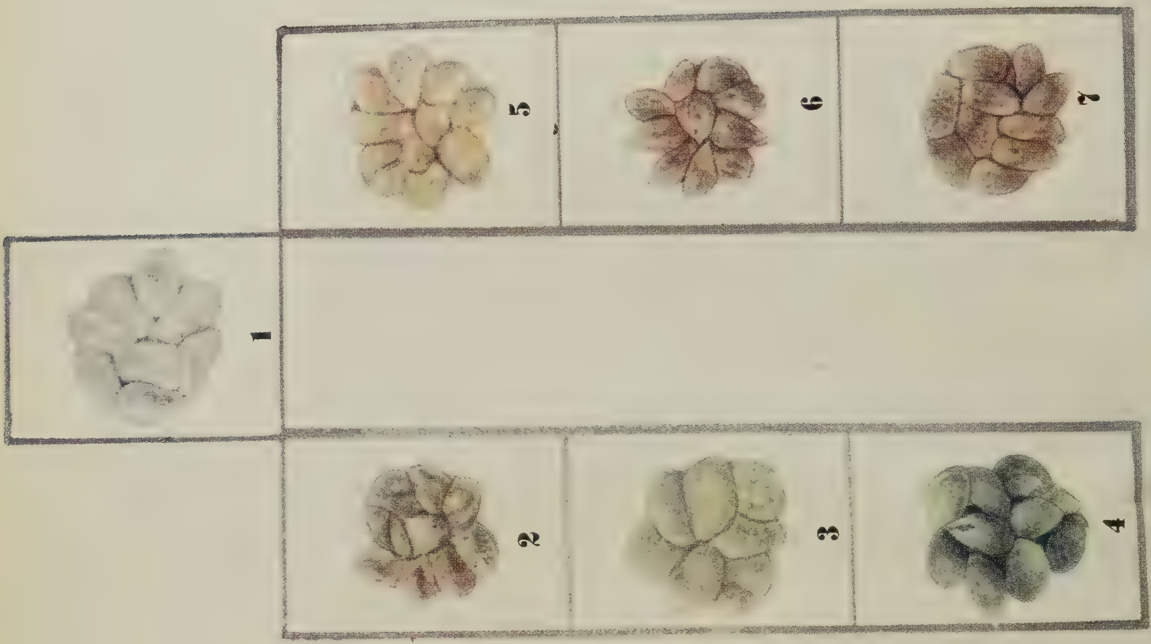
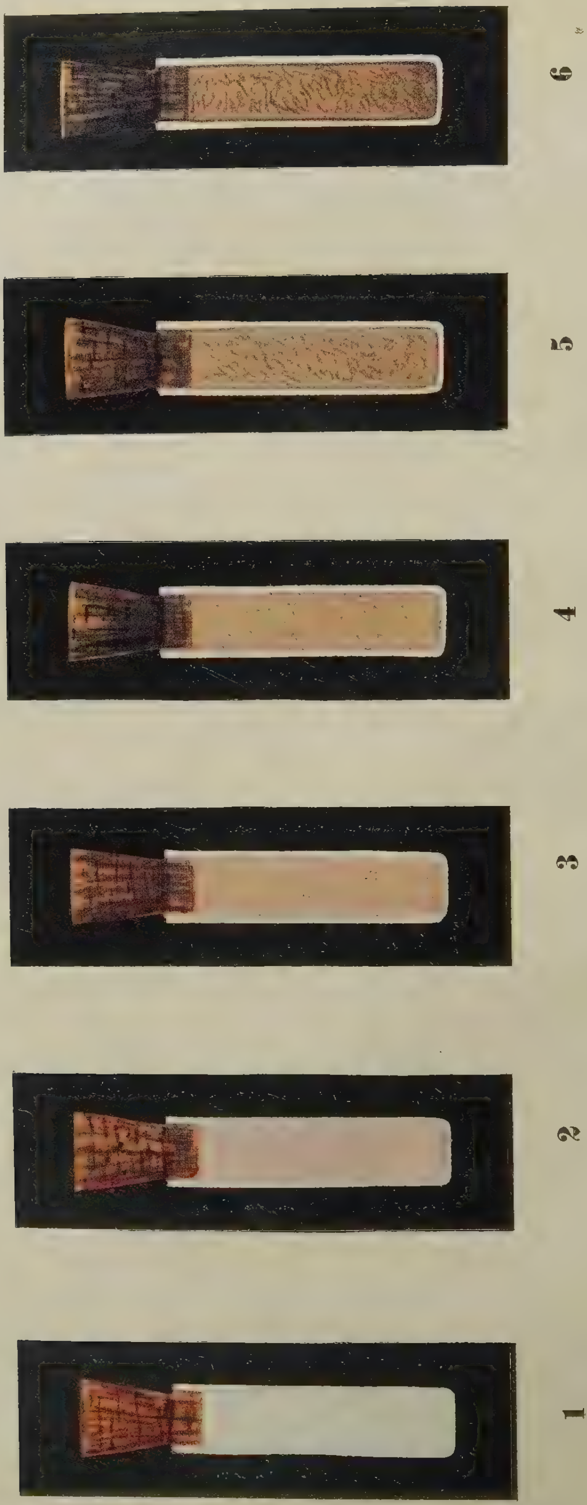


FIG. 2 American cottons

PLATE XXXVII

[*Ind. J. Agric. Sci.,* **Vol. 8, Part V**



Lint colour grades

5. *Tillers*	Number of ear bearing tillers per plant (see special schedule). Straw—strong or weak, refer to persistent and adhering leaf sheath which gives strength to the straw. Total height of the plant (see special schedule).
6. *Leaf-blade*	Only mention if it is particularly narrower or broader than the commonly occurring types.
7. *Inflorescence*	Panicle—open or compact, erect or drooping (Plate XLV) Well exserted, exserted or partly enclosed (Plate XLVI) Length of panicle (see special schedule). Number of grains per panicle (see special schedule). Glume size—short, mid-long or long (Plate XLVII) Lemma and palea—Ordinary hairy or pubescent. Colour at the early and ripe stages (Plates XLII-XLIV) Awned or awnless—If awned, tipped or medium awned or fully awned (Plates XLVIII-L) Grain shattering.—Though all varieties that shatter up to 5 per cent may be taken as non-shattering, the limits actually meant under ordinary conditions may be indicated. Sterility—Some types always exhibit a certain amount of unsetting. This may be recorded giving the maximum extent of such occurrence.
8. *Grain*	Size—Bold, medium or fine according to local classification. Length, breadth, weight of 1000 grains—Special schedule. Percentage of husk to grain—to be determined by Japanese Ci-co-ci[*] Milling quality—to be determined by *Maung*,[†] grain mixer and grain separator as used in Burma. (Plates LI and LII) Rice—White or coloured (Plate LIII) Scented or non-scented. Presence or absence of abdominal white; glutinous or non-glutinous; translucent, semi-translucent or opaque. Mention special uses to which the rice is suitable, like *pulao* rice, boiled rice, puffed rice, beaten rice, etc.

---

[*] For determining percentage of husk to grain in bulk quantities, Ci-co-ci may be used. This is a Japanese hand sheller and costs about Rs. 87-8. It can be obtained from Sreelal Champalal Importers and Engineers, 434, Mint Street, agents, in Madras. The machine has been tried in Coimbatore and found to be very satisfactory. There is absolutely no breakage of grain nor removal of bran and even small quantities up to 2lb. can be handled.

[†] *Maung* together with a set of other machines is used in Burma for determining milling qualities in rice. The whole set of machines costs about Rs. 172-8 in Burma and it is recommended that it may be used by all rice breeders in India. Except the Cole's separator which is patented, others can probably be made locally. A dimensional sketch of the standardized *Maung* used by the Rice Research Officer, Burma, is attached. About 4 lb. of the shelled grain will be put into the *Maung* and a definite number of strokes, say 500 given. The full and broken rice can then be separated. For further details reference may be made to the paper "A note on the machine used in the testing of paddy for breakage in milling" [Hayes, 1932].

Two small power machines that can be worked by electricity, one of American make and the other of Italian make are now put on the market. They are being tried by the Senior Marketing Officer, Delhi and the Rice Research Officer, Rangoon, respectively. They may be considered when the results are ready but they both cost over 600 rupees each.

9. *Physiological characters* .
- (*a*) Rapidity of germination, dormancy if any.
- (*b*) (*i*) Duration in days from sowing to flowering (special schedule).
  - (*ii*) Duration in days from sowing to ripe stage.
- (*c*) Resistance to particular diseases or pests (ordinary field resistance only).
- (*d*) Resistance to drought, floods, salinity, etc.
- (*e*) Range of adaptability—wide or restricted.
- (*f*) Yield per plant (special schedule).
- (*g*) Acre yield—lbs. (from proper replicated trials mentioning the yield of the standard variety with which it was compared).

NOTE.—Mention time of sowing, and say if the variety is time-fixed or season-fixed.

Additional information about the following may be given wherever possible :—

Root-system, meteorological conditions of the tract to which the variety belongs, and any characteristic not included before and that is worth mentioning. The paddy straw is of importance in some tracts where there is scarcity of fodder. Mention whether used as fodder and the relative yield of straw to grain.

QUANTITATIVE CHARACTERS AND SPECIAL SCHEDULE

The quantitative characters which will be dealt with in the special schedule are the following :—

(1) Height of plant cm.
(2) Number of tillers per plant
(3) Flowering duration days.
(4) Length of panicle cm.
(5) Number of grains per panicle
(6)* Size of grain, paddy and rice, length, breadth and L/B mm.
(7)† Weight of 1000 grains, paddy and rice grm.
(8) Yield of individual plant grm.

To aim at uniformity throughout India in the measurement of the above characters, the following should be observed in recording the measurements. Since all these characters are subject to great changes according to the season in which the plant is grown, it is expected that the measurements will be recorded from a crop grown in a season normal for the tract. The range of variation given here refers to what has been observed in measurements recorded in about 600 Madras rices (pure lines) grown in Coimbatore.

---

*For measuring grain a Vernier calliper is recommended. Any one of the following three may be found useful :—

(*i*) Calliper gauge with verniers—Gallenkamp—Catalogue. Costs 7/3 shillings ; is used in Coimbatore.

(*ii*) Micrometer screw gauge—Gallenkamp—costs 9 shillings—is used in Nagina.

(*iii*) Micrometer dial gauge—obtainable from Chas. Hearson, Ltd., 68, Willow Walk Bermondsey, S. E. I. London, costs nearly £2/10—is used in Burma and Pusa.

†For (7) and (8) an ordinary physical balance will do. A machine called the 'cement balonce', which can be obtained through the Scientific Instrument Co., Allahabad (Agents of Central Scientific Company, Chicago) and which costs £3/10, has been in use at Coimbatore for this work and found very satisfactory.

(1) *Height* to be measured to the nearest cm. from the base of the plant to the tip of the main panicle after the grain had ripened and before the straw starts shrinking or lodges. In the case of the awned variety, the length of the awn is to be left out of consideration.

Range—66 to 142 cm.

No. of plants to be measured in a progeny row—10.

(2) *Tillers.*—The number of ear-bearing tillers per plant to be counted when the grains are ripe and will include the main tiller as well. This is expected to be from plants grown with a spacing normal in the locality. Spacing adopted in Coimbatore is 6 in. × 6 in.

Range—2 to 11.

No. of plants to be counted in a progeny row—25.

(3) *Flowering duration.*—This is to be expressed in days from the day in which the tip of the first panicle is exserted out of the enclosing leaf sheath.

Range—55 to 172 days.

No. of plants to be observed in a progeny row—25.

(4) *Length of panicle.*—The length of the main panicle only to be measured in each plant or in its absence the panicle of the next main tiller.

Range—13·1 to 32·0 cm.

No. of plants to be measured in a progeny row—10.

(5) *No. of grains per panicle.*—Only set grains to be counted on the main panicle, the same panicles measured in (4) may be used for this.

(6) *Size of grain and rice.*—The length and breadth measurements to be made in ten paddy grains to be taken (and also the rices after removing the husk with the hand) at random from the middle portion of the main panicle only.

Range—Length paddy—5·3 to 11·5 mm. Breadth 1·9 to 3·7 mm.

No. of plants to be measured in a progeny row—10.

(7) *Weight of 1000 grains paddy and rice in grms.*—The mean of ten determinations, paddy grains to be taken at random from the bulk after a thorough drying. The weight of rice to be determined from random samples of 1000 grains taken from the sample after hulling with the Japanese machine.

(8) *Yield per plant*—To be determined when the plants are dead ripe and before the grains shatter.

Range—3·5 to 21·5 grms.

No. of plants to be weighed in a progeny row—25.

NOTE.—While the recorded measurements of the above characters in a big collection of rice varieties would give an idea of the range of variability that might be expected, the measurements being themselves averages or mean values should include an estimate of the standard error. For pure lines grown in progeny rows under uniform conditions with even spacings, measurements on 10-25 individuals as indicated for the different characters are considered enough.

SPECIMEN SCHEDULE FOR QUANTITATIVE CHARACTERS

—	Height of plant cm.	No. of tillers per plant	Flowering duration (days)	Length of panicle cm.	No. of grains per panicle	Paddy grain mm.		Rice mm.		Weight of 1000 grains grms.	Yield per plant grms.	Remarks
						Length	Breadth	Length	Breadth			
T 37	133·6±2·3	4·9±0·67	112±2·3	31·2±0·79	...	6·3±0·04	3·2±0·02	...	...	...	9·5±1·3	
T 245	100·6±1·5	8·5±0·50	90±1·9	21·8±0·46	...	8·4±0·05	3·3±0·01	...	...	...	10·5±2·1	

GENETICS OF RICE AND GENIC SYMBOLISATION

The characters in rice whose inheritance has been studied and reported so far are summarised in Appendix III. Most of the genetical results reported are from Japan, India and the United States of America. A critical study of the published papers on rice genetics reveals considerable confusion with regard to naming of morphological parts and in the description of characters (particularly colour characters) dealt with. Except where definite proof was available that a character dealt with by two different authors was one and the same though described differently, the descriptions as given by the authors have been retained. There is no doubt that some of the characters are duplicated but it is impossible to avoid this with the present confusion existing in the nomenclature.

With regard to the study of inheritance of a particular character undertaken by a research worker in India, it is suggested that he should first make sure whether he is not dealing with a character already studied and reported upon by someone else. With the existence of the Imperial Council of Agricultural Research, a co-ordinating body, it should be possible to arrange for the exchange of material between workers and opportunities already exist for them to meet and discuss genetical problems of common interest to them. It is desirable that rice botanists in India when they publish results of genetical interest should arrange to maintain the special material they may have obtained, for exchange with other workers who may be interested in similar investigations.

Although considerable work has been done on the genic analysis of individual characters, comparatively few cases of linkage have been demonstrated with certainty. Chao [1928], based on the Japanese material he worked with, has recognised four linkage groups. Ramiah [1935] (actual results unpublished) states that there is indication of three groups with regard to the genes responsible for the development of the anthocyanin pigment in various parts of the plant. Other isolated cases of linkage are also known but it is difficult to generalise, due to the existing confusion in the nomenclature. Several cases of genetic associations among various characters, both morphological and agricultural have also been reported, particularly from Coimbatore.

While the normal chromosome number in rice is $2n=24$, the occurrence of euploids (haploids, triploids and tetraploids) and aneuploids with $2n+1$, $2n+2$ and $2n+3$ has been reported both from Japan and Coimbatore.

With regard to genic symbolisation, the lack of uniformity in the method of representing genic relationships prevailing at present is obscuring the usefulness and significance of the published results. Symbols have been used indiscriminately without regard to previous use of similar symbols. The position may be summarised as below :—

1. In many cases no symbols have been used ;
2. The first two or three letters of the English alphabet have been very commonly used to explain the genetic behaviour ; and
3. Specific symbols have been used.

In the first two cases it is easy to adopt new symbols wherever definite information is available. With regard to specific symbols, many of the rice geneticists have used the same symbol to denote different characters and in some cases the same worker has used an identical symbol to denote more than one character. Appendix IV gives an idea of the present position. To remedy the existing state of affairs a new genic list of rice has been drawn up on the lines of those recommended by De Hann [1932] and using symbols adopted in maize for similar characters [Emerson *et al.*, 1935]. Since it is very necessary that there should be a common understanding not only among workers in India but also with rice geneticists outside India, this list is being circulated to all of them through the Imperial Bureau of Plant Breeding and Genetics, Cambridge, and the final agreed list, when ready, will be published in India. It is expected that this will bring about an interdational understanding of the genetics of rice and facilitate exchange of material with foreign geneticists for rice work in India. Nagao [1937] has also referred to the existing confusion in genic symbolisation in rice and his list of known genes will be obtained for comparison and check with ours.

REFERENCES

Chao, Lien Fang (1928). *Genetics* **13**, 133

Chevalier, P. A. (1932). *Revue de Botanique* **12**, 1014

De Hann, H. (1932). *Genetica* **15**, 1

Emerson, R. A.; Beadle, G. W.; and Faser, A. C. (1935). *Corn. Univ. Expt. Stat. Mem.* 180

Flakesberger, C. A. (1932). *Bull. App. Bot. Leningrad. Sec. A* (**4**), 43

Gotoh, K. and Okura, E. (1933). *J. Soc. Trop. Agric. Formosa* **5**, 363

Hayes, A. (1932). *Agric. and Livestock in Ind.* **2**, 162

Nagao, Masato (1937). *Jap. J. Bot.* **8**, Abstract 273

Ramanujam, S. (1938). *Annals of Bot.* **2**, 107

Ramiah, K. (1935). *Proc. Assn. Econ. Biol. Coimbatore* **3**, 51

Roschevicz, R. J. (1931). *Bull. Appl. Bot, Gen, and Plant Breeding* **27**, No. 4

Appendix I

NOTE ABOUT THE NAMING OF THE PARTS OF THE RICE PLANT

Plate XXXVIII gives the names of the parts. They are self-explanatory and certain additional notes are herein provided.

Leaf axil.—The axil refers to the inside of the leaf sheath base just above the node and pulvinus. Since the presence of anthocyanin pigment in the axil is controlled by Mendelian genes which are often associated with other genes controlling pigment in other parts of the plant, the examination of the axil becomes necessary while studying the inheritance of pigment. Such examination is best done by cutting away a portion of the stem from a shoot at the second or third node above ground level along with the sheath and then splitting it open removing the attached internode from its base. Such an opened axil is shown in the plate.

Septum.—By septum is here meant the partition or diaphragm between two internodes just inside the node. It is best seen by cutting the tiller just below the second or third node from ground level and looking through the cut end. The presence of anthocyanin pigment in septum is often associated with the presence of such pigment in other parts of the plant like lemma, palea and stigma.

Pulvinus.—This term is used to denote the swollen growth zone at the base of the leaf sheath just above the point of its insertion on the stem and does not form part of the node. In Bengal and Bihar this term has been used to denote the two triangular portions connecting the leaf blade with the sheath and from which the auricle and the ligule start, which is probably not correct. These triangular portions may probably be more appropriately called junctura.

Glumes.—There has been great diversity in naming the four glumes of the rice spikelet. It is now agreed that the two rudimentary sterile glumes should be simply called 'glumes' and the two flowering glumes (3rd and 4th) as 'lemma and palea, respectively.

Apiculus.—The term will be used to denote the tips of the lemma and palea.

Panicle.—The term will be used to denote the whole ear, the branches to be termed as simply panicle branches and the individual flower, a spikelet.

Exsertion.—The term is to be used to denote the portion of the peduncle of the panicle from the junctura of the boot or flag leaf to the lowermost node of the rachis.

Tiller.—Tiller denotes a shoot arising from the ground level as distinct from branching which refers to the shoots arising from the upper nodes in the stem. The number of tillers per plant in the schedule refers to the number of ear-bearing shoots.

Grain.—It has been agreed that the term 'paddy' should be retained to denote the grain in husk while the term rice will refer only to the husked grain.

Appendix II

NOTES ABOUT PIGMENT AND OTHER CHARACTERS

The greatest amount of diversity in nomenclature is to be found when dealing with descriptions of various pigments occurring in different parts of the rice plant, more particularly with those relating to the lemma and palea. The Botanical Sub-committee, which discussed the question, considered that specially prepared colour plates are better than standard colour charts. The charts now presented have been specially prepared by the Paddy Specialist, Coimbatore.

Anthocyanin pigmentation.—The occurrence of anthocyanin pigmentation in some part of the plant is extremely common and different localisations of this colouring form some of the most striking varietal characters. The pigment which occurs in solution in the cell-sap has been generally referred to as purple in the Coimbatore publications. The actual appearance, however, varies considerably according to the concentration of the pigment and the colour of the tissue in which it is present. Thus in the epidermis of a dark green sheath, it appears bluish, whereas in an otherwise colourless stigma it appears reddish in low concentration and almost black when highly concentrated. The pigment itself does not appear to show variation when examined with a lens. Sometimes the play of light and the development of the plant influence the intensity of the pigment. Plants on the borders of plots fully exposed to light show rather more pigmentation than plants in the interior of the plot. Similarly plants growing very vigorously, say in an unusually fertile patch, show less colouration than plants in an unfavourable situation due to, say, lack of water or due to over-crowding. The different parts of the plant where the presence of pigment has been studied are dealt with below.

Coleoptile.—This is either green or shows shades of purple. Purple coleoptile is always associated with some colour in the leaf blade or lemma and palea.

Leaf sheath (Plate XXXIX).—The common colours noted are green or purples of different shades. In the purple colouring the colour is particularly distinct in the sides and the edges. The colouring when it occurs, though frequently most intense in the lower half of the sheath, always extends up to the connection with the lamina and often into the ligule. The lower sheaths, especially such as are poorly developed, show the maximum amount of colouring. Among the purples, apart from the grades of intensity, three types may be distinguished, (*i*) one with self colour only, where the colour is confined to the parenchymatous tissue between the vascular bundles ; (*ii*) one with purple lines only, *i.e.*, the colour confined to the vascular bundles, the intervening tissue being green, and (*iii*) where the colour is present in both the bundles and the intervening tissue. In some cases the colour is present only in the axil and inside of the sheath with green outside and giving a false presence of colour, the same showing through.

Even among the greens, types exist which vary in their intensity, some of the lighter types appearing pale yellow but it is rather difficult to differentiate them.

Internode (Plate XL).—Apart from anthocyanin pigment there are two main types, green and gold, the latter always associated with gold colouring of degrees on the lemma and palea. Where the anthocyanin pigment is present it appears in lines, due to the pigment being confined to the vascular bundles. This lining is normally associated with a certain amount of lining in the leaf sheath. It is a common character found in very many varieties and shows great variation. In some types the lining is faint and scarcely noticeable, developing only when the internode is exposed to strong light. Many intermediate forms exist between such types and those showing the fullest development where the whole internode is deeply coloured in shades varying from almost red to almost black. Such deeply coloured types are usually included under purple lining as examination shows that the pigment is present mainly in the vascular bundles although it spreads into the surrounding cortex sufficiently to give the appearance of self colouring.

Ligule.—Either white or shades of purple, the latter generally going with the in tensity of colour in the leaf sheath.

Auricle.—Either white (green) or shades of purple. Where the auricle is purple it is associated with purple colouring in the pulvinus.

Leaf axil.—Either white or shades of purple. The purple may or may not be present at the actual base, its presence there going with colour in stigma.

Septum.—Light yellow or cream, pink and shades of purple.

Leaf blade (Plate XLI).—Besides the green type three other types of anthocyanin colouration in the leaf-blade can be made out. In one, the pigment is present only at the blade tip and the margins; in the second this colour appears to spread down from the tip and margins giving a purple wash, darker at the margins and lighter in the centre: in the third the whole leaf blade is pigmented. There may occur some intermediate types between 1 and 2 and also between 2 and 3 but it is rather difficult to differentiate them clearly.

All the types with some purple in the leaf blade have necessarily colour in the sheath while the converse is not true. Colour in the leaf blade is always associated with some form of anthocyanin pigment in the lemma and palea.

Among greens there are types with different intensities some looking more yellowish than others but such variation is made out more by the mass effect rather than from individuals.

Glumes.—The pigment characters of the glumes are quite simple. There are only three colours.—White (straw), brown and purple. The brown occurs in the types which have rich ripening brown colour (also called tawny) in the lemma and palea. The purple colour usually occurs where the lemma and palea have got the pigmentation not only at the apiculus but where it spreads down appreciably.

Lemma and palea (Plates XLII-XLIV)—The most usual colour of the lemma and palea is a light green, ripening to pale straw but there are numberless types with other colours. Of these one of the commonest is some form of what may be described as golden colouring, though this varies in different types from orange yellow to reddish brown at the time of flowering, becoming rather darker and duller on ripening. The pattern of distribution of this gold colour on the lemma and palea also varies in different types (Plate XLIV). When dealing with colour in lemma and palea one has to bear in mind that often the colour, which is to be seen in the young stages (flowering), changes into something quite different at the ripe stage and this necessitates the inclusion in the description of the colour whether it is the ripening colour or not. Where the ripening colour is different the examination of the panicle for any unset spikelets in it immediately shows out the colour in the young stage, as such spikelets retain it for a long time. Where the anthocyanin pigment appears on the lemma and palea, it may either be confined to the apiculus or all over, the intensity again varying in different types from light red to dark purple (almost black). All the lemma and palea colours observed in Coimbatore have been depicted in the plates, the top line showing the green stage and the bottom line the corresponding ripe stage. There are altogether nineteen types represented in the plates and it is possible that all the known colours of the lemma and palea could be matched with any one of these. There may occur often in hybrid material some types that will not strictly match with those in the plates but they are not considered of importance. The term straw applied to the ripe colour of the lemma and palea is rather variable and includes some types definitely brighter than others. The dull-looking types are those where the rice inside is coloured, red, brown, etc., and the colour showing through.

Awns.—The main colours occurring are white or straw, pink, brown and purple.

Rice (Plate LIII).—It is not known what the colouring matter is that occurs in coloured rices but it is suspected that the colour in the dark purple (black) rice may also be anthocyanin. Part of it is soluble in water as the water in which this rice is soaked becomes coloured. The most usually occurring colours in rices are white and various shades of red. The type with dark purple (black) rice is rather rare and the other types represented in the plate are mostly of genetic interest. Pure-breeding types of these unusual colours have been obtained from hybrids and are maintained in the Coimbatore collections.

Size of grain is important and is often utilised for classification purposes. The grain varies both in the length and in the breadth and the ratio length/breadth often gives an indication of the coarseness or fineness. The terms coarse or fine are only relative to the tract, as what is termed fine in one place may be considered coarse in another and *vice versa.*

Awn-distribution.—The existence of awns is an important varietal character in rice. Though the development of the awns is subject to considerable environmental influences, chief of which being the spacing given to plants in transplanting, it is a genetical character, simple in some cases and complicated in others. Variations obtain in the different types both in the length of the awns and in their distribution, the former being probably a more dependable basis for identification. The same plant may show longer awns in its later tillers, and awning is best judged by examining the main tillers.

Based roughly on the length of the awns, three groups can be made out besides the awnless type and these are given in Plates XLVIII—L. It is possible to come across types with awn length intermediate between any two types given in the plate and it is more from the consideration of simplicity that only three groups are given. The limits of each group are, however, indicated in the plates.

NOTE.—Coloured rice is not scientifically accurate and it must be remembered the colour is confined only to the testa or seed coat.

Appendix III

LIST OF CHARACTERS IN RICE AND THEIR MODE OF INHERITANCE AS REPORTED UP TO 1937

Character	F_2 segregation and ratios recorded	
Anthocyanin pigment	Presence : absence	3 : 1 ; 9 : 7
Apiculus	Coloured : colourless	3 : 1 ; 9 : 7 ; 15 : 1 ; 27 : 37 ; 81 : 175 ; 162 : 94
	Purple : red : colourless	9 : 3 : 4
	Purple : red : pale yellow	27 : 9 : 28
Auricle	Coloured : colourless	3 : 1 ; 9 : 7 ; 15 : 1 ; 27 : 37
	Green : purple	15 : 1
Awn colour	Coloured : colourless	3 : 1 ; 9 : 7
	Black : reddish brown	3 : 1
	Brown : colourless	3 : 1
	Purple : colourless	3 : 1
	Purple : red	3 : 1
	Purple : red : white	9 : 3 : 4
	Red : colourless	3 : 1
	Red : brown : colourless	9 : 3 : 4
	Red : white	9 : 7
	Tawny : non-twany	3 : 1
Awning	Awned : awnless	3 : 1
	Fully awned : partly awned	3 : 1
	Fully awned : partly awned : awnless	9 : 6 : 1
	Fully awned : mostly awned : rarely awned : awnless.	12 : 1 : 2 : 1
	Partially awned : awnless	3 : 1
Chlorophyll	Green : albino	3 : 1 ; 9 : 7 ; 15 : 1 ; 63 : 1
	Green : dull-yellowish green	3 : 1
	Green : lutescent	3 : 1
	Green : variegated (duplicate genes)	3 : 1 ; 15 : 1
	Green : variegated : albino	9 : 3 : 4
	Green : virescent	3 : 1
	Green : virescent yellow : albino	9 : 3 : 4
	Green : virescent yellow : variegated	9 : 3 : 4
	Green : white striped	3 : 1
	Green : white striped : albino	12 : 3 : 1
	Green : xantha	3 : 1
	Green : yellow	3 : 1 ; 15 : 1
	Green : yellow striped	3 : 1

Appendix III—*contd.*

Character	F_2 segregation and ratios recorded	
Flowering . . .	Early : late	3 : 1 ; 1 : 2 : 1 ; 9 : 7 ; 15 : 1
	Late : early	3 : 1 ; 9 : 7
Glume (outer) colour .	Green : purple	15 : 1
	Purple : colourless	3 : 1 ; 9 : 7
	Red : colourless	3 : 1 ; 9 : 7
	Tawny : non-tawny . . .	3 : 1
Glume (outer) size .	Short : long	3 : 1 ; 1 : 2 : 1 ; 15: 1
Habit . . .	Erect : floating	15 : 1
	Erect : spreading : prostrate . .	1 : 2 : 1
	Lazy : erect	3 : 1
	Procumbent : normal . . .	3 : 1
	Prostrate : erect	3 : 1
	Spreading : erect	3 : 1
Inhibitor (see under leaf-blade).	Green : purple-blade . . .	13 : 3
	Light : purple-blade . . .	3 : 1
Internode colour .	Coloured : colourless . . .	3 : 1
	Green : gold	3 : 1
	Light brown : colourless . . .	3 : 1
	Light purple : colourless . . .	3 : 1
	Purple : colourless	3 : 1 ; 9 : 7 ; 27 : 37
	Purple lining : colourless . . .	3 : 1
	Purple: yellowish brown : light brown	12 : 3 : 1 ; 9 : 3 : 4
Kernel endosperm .	Non-glutinous : glutinous . .	3 : 1
Leaf-blade colour .	Green : pink	3 : 1
	Green : purple	13 : 3
	Purple : green	3 : 1 ; 9 : 7 ; 27 : 37
	Purple : striped : green . . .	27 : 9 : 28
Leaf-blade twisting .	Normal : rolled	3 : 1
Leaf-margin . .	Coloured : colourless . . .	3 : 1
Leaf-sheath colour .	Coloured : non-coloured . . .	3 : 1 ; 9 : 7 ; 15 : 1 ; 27 : 37
	Purple : green	3 : 1
	Purple : striped : green . . .	27 : 9 : 28
	Red : green	3 : 1
	Reddish : green	9 : 7

Appendix III—*contd.*

Character	F_2 segregation and ratios recorded	
Lemma and palea (anomalies).	Normal : abnormal (open glumes)	3 : 1
Lemma and palea colour.	Ash black : yellow brown	3 : 1; 9 : 7; 27 : 37
	Black : inter : yellow	9 : 6 : 1
	Black : straw	3 : 1; 9 : 7
	Black : yellow	9 : 7; 15 : 1
	Black : yellow brown	3 : 1
	Black : yellow : blackish brown	36 : 21 : 7
	Blackish violet : apex blackish violet : red blackish : apex reddish black : yellowish white.	27 : 9 : 9 : 3 : 16
	Coloured : colourless	3 : 1; 9 : 7; 15 : 1; 27 : 37; 81 : 175
	Colourless : gold	3 : 1
	Dark furrows : ripening gold	3 : 1
	Dark furrows : gold	3 : 1
	Dark gray : dark orange streaked : white : orange streaked.	9 : 3 : 3 : 1
	Dark gold : ripening gold	3 : 1
	Even coloured : intermediate : mottled.	1 : 2 : 1
	Green : blackish green	3 : 1
	Green : blackish green : light brown : brown.	9 : 3 : 3 : 1
	Green : dark furrows	3 : 1
	Green : light brown	3 : 1
	Green : patchy gold : gold	1 : 2 : 1
	Piebald dark furrows : dark gold	3 : 1
	Piebald : green	3 : 1
	Purple : colourless	3 : 1; 9 : 7
	Purple : green	3 : 1
	Purple : non-purple	3 : 1
	Purple : purple striped : brown : yellow.	9 : 3 : 3 : 1
	Purple : reddish brown : dark gray : white	9 : 3 : 3 : 1
	Red : white	3 : 1; 9 : 7
	Red : ripening brown : white	9 : 3 : 4
	Red : colourless	3 : 1; 9 : 7
	Tawny : non-tawny	3 : 1
	Tip gold : gold : ripening straw : ripening gold	9 : 3 : 3 : 1
	White : red	3 : 1
	Yellow : brown	3 : 1
	Yellow : inter : deep brown	9 : 6 : 1

Appendix III—*contd.*

Character	F_2 segregation and ratios recorded	
Lemma and palea colour—*contd.*	Yellow : red	3 : 1
	Yellow brown : colourless	13 : 3
	Yellowish brown : red	3 : 1
	Yellow : inter : brick red	9 : 6 : 1
Lemma and palea shelling.	Easy : tough chaff shelling	3 : 1
	Tough : easy chaff shelling	3 : 1
Ligule absence	Normal : liguleless	3 : 1
Ligule colour	Coloured : colourless	3 : 1 ; 9 : 7 ; 27 : 37
	Purple : colourless	3 : 1
Lodging	Normal : brittle	3 : 1
	Lodging : non-lodging	3 : 1
Node colour	Purple : green	3 : 1 ; 9 : 7 ; 27 : 37
Panicle anomalies	Normal : aberrant	3 : 1
Panicle density	Lax : dense	3 : 1
	Lax : normal	3 : 1
	Normal : compact	3 : 1
	Spreading : close	9 : 7
Panicle exsertion	Partially emerged : tipe-emerged : enclosed	49 : 3 : 12
Panicle (shape of neck)	Normal : sinuous	15 : 1
Pericarp colour	Black : inter : white	1 : 2 : 1
	Brown : yellowish brown : white	9 : 3 : 4
	Brown : white	3 : 1
	Full red : gray brown : white	9 : 3 : 4
	Gold : yellow	3 : 1
	Purple : brown	9 : 7
	Purple : red : white	12 : 3 : 1
	Purple : white	3 : 1
	Red : gold	3 : 1
	Red : gray brown	3 : 1
	Red : white	3 : 1 ; 9 : 7 ; 15 : 1
	Reddish brown : yellowish brown : white.	9 : 3 : 4
	Red piebald : pale piebald : white	1 : 2 : 1
	White : amber	3 : 1
	Light red : white	3 : 1
	Dark red : light red	9 : 7
	Red : amber : white	1 : 2 : 1

Appendix III—*contd.*

Character	F_2 segregation and ratios recorded	
Pistil number	One : many	3 : 1
Pulvinus colour	Coloured : colourless	3 : 1 ; 9 : 7 ; 27 : 37
	Purple : non-purple	15 : 1
Resistance to disease	Resistance : susceptibility to *Leptosphœria* (Catt.)	3 : 1
	Resistance : susceptibility to *Melanomma oryzæ*	3 : 1
	Resistance : susceptibility to *Piricularia oryzæ*	3 : 1 ; 9 : 7
	Resistance : susceptibility to *Helminthosporium oryzæ*	3 : 1
Root colour	Coloured : colourless	9 : 7
Scentedness	Scented : non-scented	3 : 1 ; 9 : 7 ; 27 : 37
Spikelet arrangement	Cluster : inter : non-cluster	1 : 2 : 1
Spikelet attachment	Non-shedding : shedding	3 : 1
	Shedding : non-shedding	15 : 1
Spikelet length	Short : long	3 : 1
	Normal : large	3 : 1
	Length/breadth ; 3·14 : 3·44 : 3·88	1 : 2 : 1
Spikelet shape	Round : long	3 : 1
Spikelet weight	High : mid-high : low ; 2·144 : 2·075 : 1·910 mmg.	1 : 2 : 1
Stature of plant	Dwarf : tall	3 : 1
	Short : tall	3 : 1
	Tall : dwarf	3 : 1
	Tall : dwarf I : dwarf II : dwarf III	9 : 3 : 3 : 1 ; 9 : 7
	Tall : short	3 : 1

Appendix III—*concld.*

Character	F_2 segregation and ratios recorded	
Sterility	Normal : abnormal (narrow leaf and open glumes)	3 : 1
	Normal : abnormal (non-dehiscence of anthers, aborted pollen grain)	3 : 1
	Fertile : awned sterile	3 : 1
	Fertile : barren sterile	3 : 1
	Fertile : completely sterile	3 : 1
	Fertile : male sterile	3 : 1
	Fertile : paleaceous sterile	3 : 1
	Fertile : partial sterile	3 : 1
	Fertile : semi sterile	3 : 1
	Fertile : semi sterile (slender and semi sterile)	3 : 1
	Fertile : sponginess	3 : 1
	Fertile : staminodal sterile	3 : 1
	Fertile : sterile (non-dehiscence of anthers)	3 : 1
	Fertile : sterile (degeneration of pistils)	3 : 1
	Fertile : sterile (shrivelled stamens)	3 : 1
	Fertile : sterile (absence of medium ribs in the leaves, twisted leaf base, abnormal branching, pistils degenerate into the form of a leaf and the occurrence of flowering twice a year)	3 : 1
	Fertile : asynaptic sterile	3 : 1
Stigma colour	Coloured : colourless	3 : 1 ; 27 : 37 ; 81 : 17
	Purple : green (white)	9 : 7
	Colourless : coloured (?)	15 : 1

Appendix IV

LIST OF GENES USED BY VARIOUS WORKERS TO DENOTE CHARACTERS IN RICE

A	With **BC** produces reddish grains, Kato and Ishikawa, 1931 ;
	Complementary to **N** for red grain in the presence of **R**, Parnel *et al.*, 1922 ;
	Tall plant, Akemine, 1923, Miyazawa, 1934 ;
	Heading time, Namura & Yamazaki, 1925 ;
	Red apiculus, Sugi & Kitagawa, 1926 ;
	Sterility (fertility), Ishikawa, 1927, Terao ;
	Awnedness, Jones, 1927 ;
	With **BC** produces purple leaf blades, Jones, 1930 ;
	Necessary with **P** to produce purple pericarp, Ramiah, 1931 ;
	General anthocyanin gene, Kadam, 1934 ;
	Earliness, Sethi *et al.*, 1936 ;
$\mathbf{A_1}$ $\mathbf{A_2}$	White auricles, Mitra and Ganguli, 1932 ;
$\mathbf{An_1}$ $\mathbf{An_2}$	Awn development, Chao, 1928 ;
$\mathbf{Ap_1}$ $\mathbf{Ap_6}$	Colour in apiculus, Chao, 1928 ;
B	With **CR** purple awn, Kato ;
	Stigma colour, Hector, 1916 ;
	Brown ground colour of glumes, Nagai, 1921 ;
	One of the complementary genes for glume colour ;
	Tall plants, Akemine, 1925 ;
	Heading time, Namura & Yamazaki, 1925 ;
	Modifier of awns, Nagai, 1926 ;
	Semi-sterility, Ishikawa, 1927 ;
	Awnedness, Jones, 1927 ;
	With **P** & **S** produces purple leaf, Yamaguti, 1931 ;
	Earliness, Sethi *et al.*, 1936 ;
$\mathbf{B_1}$ $\mathbf{B_2}$	Black colour of inner glumes, Mitra, 1937 ;
C	Chromogen gene, Kato, Hector, 1916 ; Nagai, 1921 ; Chao, 1928 ;
	Ripening brown apices, Takezaki, 1923 ;
	Heading time, Namura & Yamazaki, 1925 ;
	With **RB** purple, with **R** red colour in apiculus, Lee, 1927 ;
	With **P** produces purple awns, Jones, 1930 ;
	Clustering of spikelets, Ramiah, 1931 ;
	Colour in sheath, etc., Mitra & Ganguli, 1932 ;
	Lateness, Sethi *et al.*, 1936 ;
	Blackish green, lemma and palea, Mitra, 1937 ;

Appendix IV—*contd.*

c_1 c_2	Yellow chlorophyll deficiencies, Ramiah, 1930 ;
d	Dwarfness, Nagai, Yamaguti, 1931 ;
d_1 to d_5	Dwarfness, Kadam, 1937 ;
E	Even distribution of colour, Parnell, 1922 ;
	Enclosed earheads in sheath, Sethi *et al.*, 1937 ;
E_1 E_2	Earliness, Ramiah, 1933 ;
	Spreading panicles, Mitra and Ganguli, 1932 ;
E_3 E_4	Earliness, Ramiah, 1933 ;
El	Elliptic grains, Parnell ;
F	Fertility, Kondo ;
F_1 F_2 F_3	Heading time, Yamaguti, 1927, 1931 ;
Fx	Heading time, Yamaguti, 1927 ;
G	Necessary with **R** to produce red glumes, alone gray colour, Kato ;
	Gold glume, Parnell, 1917, 1922 ;
	In the presence of **N** or **n′** ; gives paleaceous sterile, Nagai, 1926 ;
	Glutinous rice, Enomoto, 1929 ;
	Purple glume, Ramiah 1930 ;
	Green plants, Mitra *et al.*, 1934 ;
G_1 G_2	Length of outer glume, Chao, 1928 ;
	Outer and inner glumes green, Mitra and Ganguli, 1932 ;
gl	Glutinous rice, Chao, 1928 ;
gw	Green and white striped plants, Ramiah, 1935 ;
gy	Green and yellow striped plants, Ramiah, 1935 ;
H	Inhibitor of orange streaking, Kato ;
H_1 H_2	Ripening black glume colour, Chao, 1928 ; Mitra and Ganguli, 1932 ;
H_1 H_2 H_3	Height in plants, Ramiah, 1933 ;
	Light red rice, Parnell, 1922 ;
	Inhibits gold glumes, Parnell, 1922 ;
	Inhibits lateness, Ramiah, 1933 ;
	Inhibits purple colour in leaf blades, Kadam, 1936 ;
I_1	Inhibits late flowering, Ramiah, 1933 ;
In	Internode colour, Chao, 1928 ;
j	Short glumes, Parnell ;
k	Compact panicle, Nagai ;
Ka, Kb	Density of panicles, Takezaki, 1932 ;
l	Lutescent seedlings, Ramiah, 1935 ;
L	Lateness, Ramiah, 1933 ;
	Light brown glumes, Mitra, 1937 ;

Appendix IV—*contd.*

$\mathbf{L_1}$	Lateness, Ramiah, 1933 ;
Ls	Leaf sheath coloured, Chao, 1928 ;
m	Glutinous rice, Yamaguti ;
N	Development of awn, Nagai ;
	Purple node, Mitra and Ganguli, 1932 ;
$\mathbf{N_1}$	Normal fertility, Nagai, Multiple allelles ;
$\mathbf{n_1}$	Staminoidal sterility, Nagai, Multiple allelles ;
n	Roll-leaved fertile, Nagai, Multiple allelles ;
O	Chromophelein gene, Nagai (completely linked with **c**)
P	Purple pericarp, Parnell, 1922 ;
	(Presence of **A** necessary) ;
	Purple colour of stigma, Hector, 1916 ;
	Partial emergence of earhead, Sethi *et al.*, 1937 ;
$\mathbf{P'}$	Purple pigment, Nagai ;
$\mathbf{P_1}$	Colour in leaf, Yamaguti, 1931 ;
	(Complementary with **S B**)
	Red pericarp, Mitra and Ganguli, 1932 ;
$\mathbf{P_2}$	Amber pericarp, Mitra and Ganguli, 1932 ;
$\mathbf{Pr_1}$	Red pericarp, Chao, 1928 ;
$\mathbf{Pr_2}$	Purple pericarp, Chao, 1928 ;
Ps	With bands plant produces purple stigma, Yamaguti, 1931 ;
R	Gold pericarp, Parnell, 1922 ;
	Red awns, Kato, Nagai ;
	Complementary with **C** to produce red colour in glumes, Kato ;
	With **C** gives red apices, Takezaki ;
	One of the complementary genes for colour, Yamaguti ;
$\mathbf{R'}$	Purple colour anthocyanin gene, Nagai ;
Ro	Root colour, Kadam, 1932 ;
$\mathbf{R_1}$ $\mathbf{R_2}$	Red pericarp, Ramiah, 1935 ;
s	Semi-sterility, Ishikawa ;
	In the presence of **N** gives awned sterile, Nagai ;
	Glume colour, Yamaguti, 1927 ;
S	Lax panicle, Ramiah, 1931 ;
	Spreading habit, Mitra & Ganguli, 1932 ;
Sa	Stigma coloured, Chao, 1928 ;
Sp	Short spikelet, Chao, 1928 ;
$\mathbf{S_1}$ $\mathbf{S_2}$	Complementary colour genes for glume apex and outer plumes, Yamaguti ;
$\mathbf{Sh_1}$ $\mathbf{Sh_2}$	Grain shedding, Kadam 1936 ;

Appendix IV—*concld.*

T	Tipped gold glume, Parnel, 1922 ; ' Tip-emerged ' of panicle out of boot-leaf, Sethi *et al.*, 1937 ;
Ty	Tawny colour in glume apices and awns, Chao, 1928 ;
u	Glutinous endosperm, Takahashi ;
W	White striped plants, Mitra *et al.*, 1934 ;
w	Albino seedlings, Kadam, 1934, Ramiah, 1935 ;
$\mathbf{W}_1$	Full awned, Mitra and Ganguli, 1932 ;
$\mathbf{W}_2$	Intermediately awned, Mitra and Ganguli, 1932 ;
y	Lethal yellow seedlings, Kadam, 1934, Ramiah, 1935 ;
Y	Yellow glumes, Mitra, 1937.

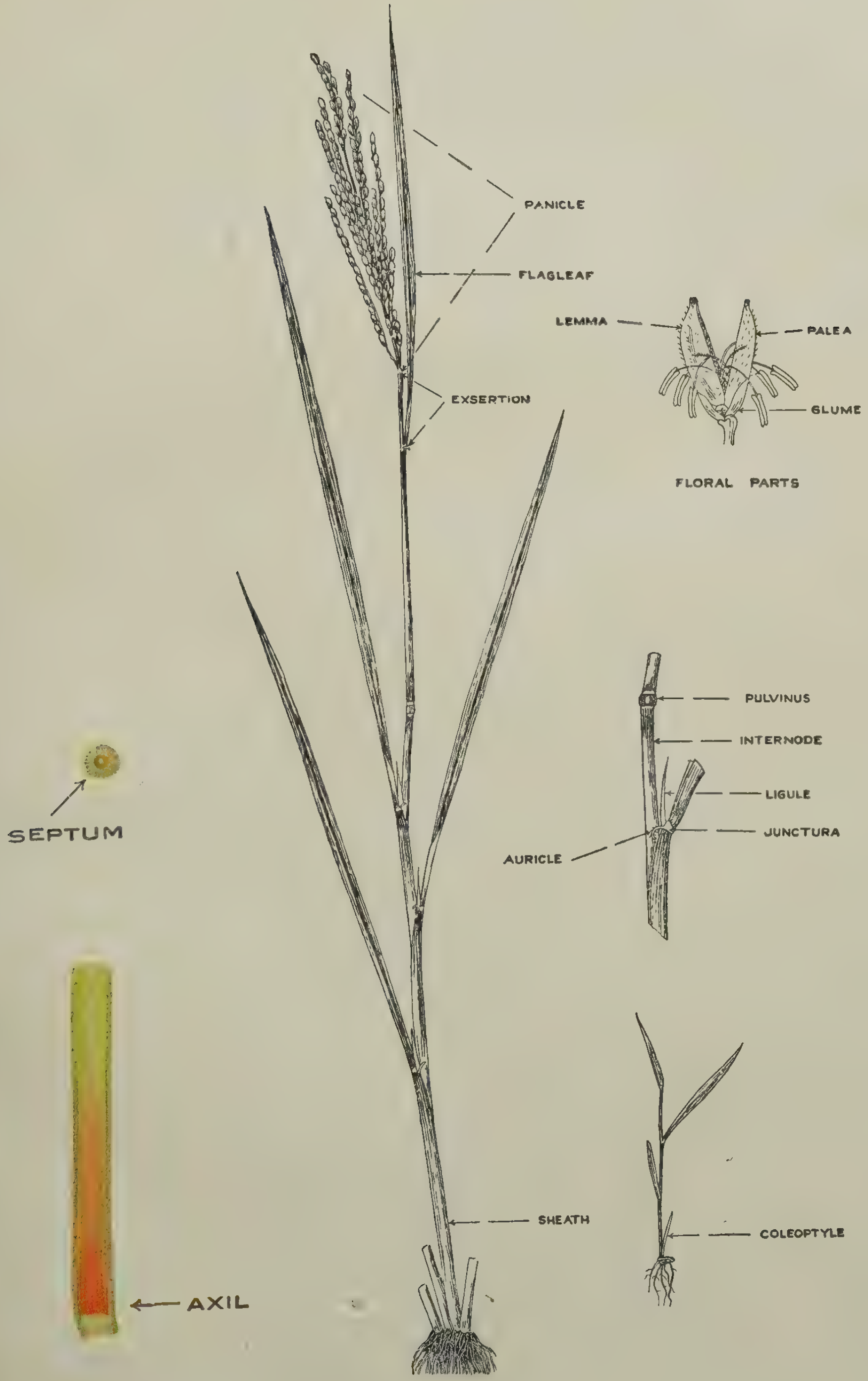
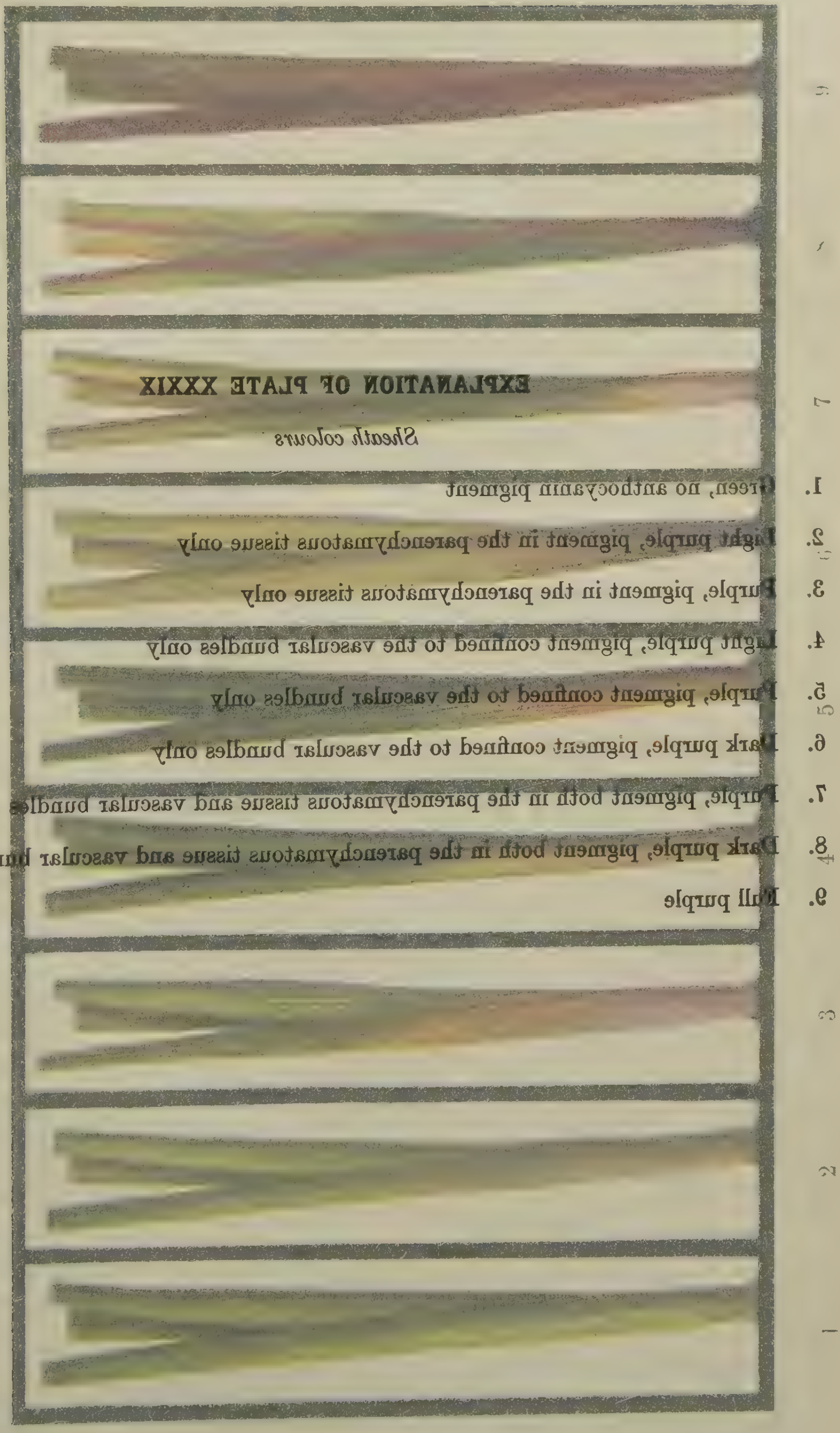

PANICLE
FLAGLEAF
EXSERTION
LEMMA
PALEA
GLUME
FLORAL PARTS
PULVINUS
INTERNODE
LIGULE
JUNCTURA
AURICLE
SEPTUM
AXIL
SHEATH
COLEOPTYLE

PLATE XXX

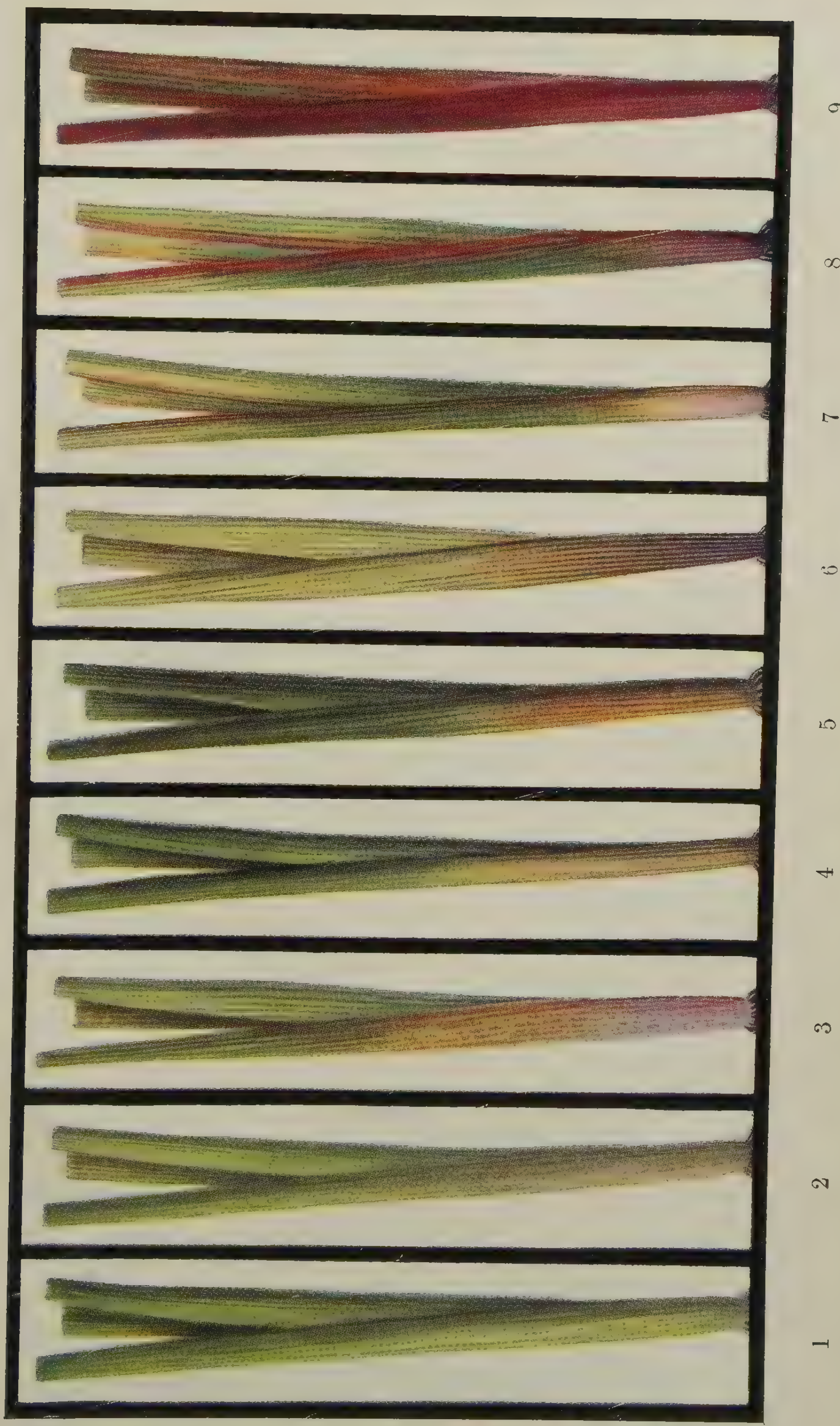


SHEATH COLOURS

EXPLANATION OF PLATE XXXIX

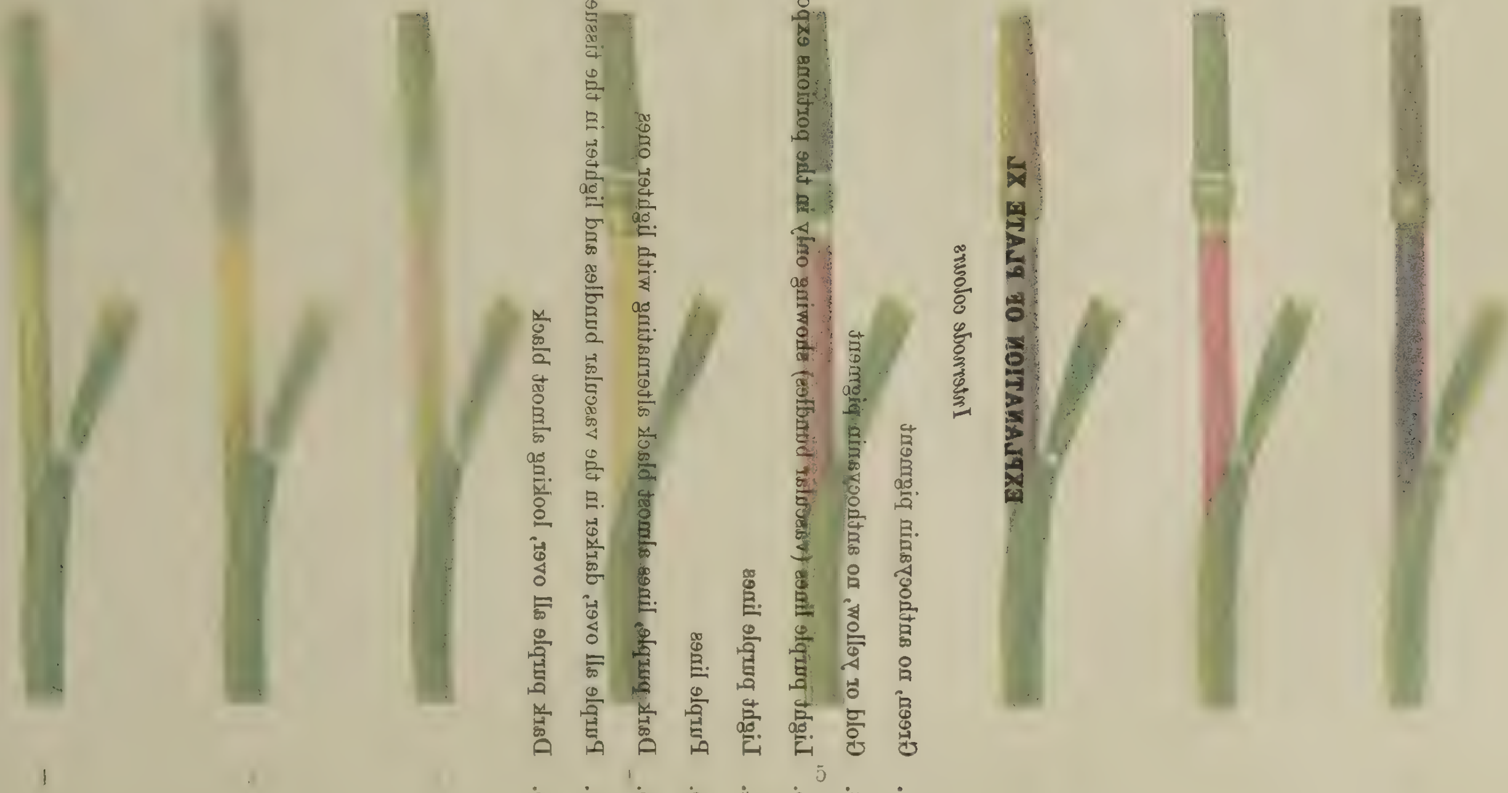
Sheath colours

1. Green, no anthocyanin pigment
2. Light purple, pigment in the parenchymatous tissue only
3. Purple, pigment in the parenchymatous tissue only
4. Light purple, pigment confined to the vascular bundles only
5. Purple, pigment confined to the vascular bundles only
6. Dark purple, pigment confined to the vascular bundles only
7. Purple, pigment both in the parenchymatous tissue and vascular bundles
8. Dark purple, pigment both in the parenchymatous tissue and vascular bundles
9. Full purple



SHEATH COLOURS

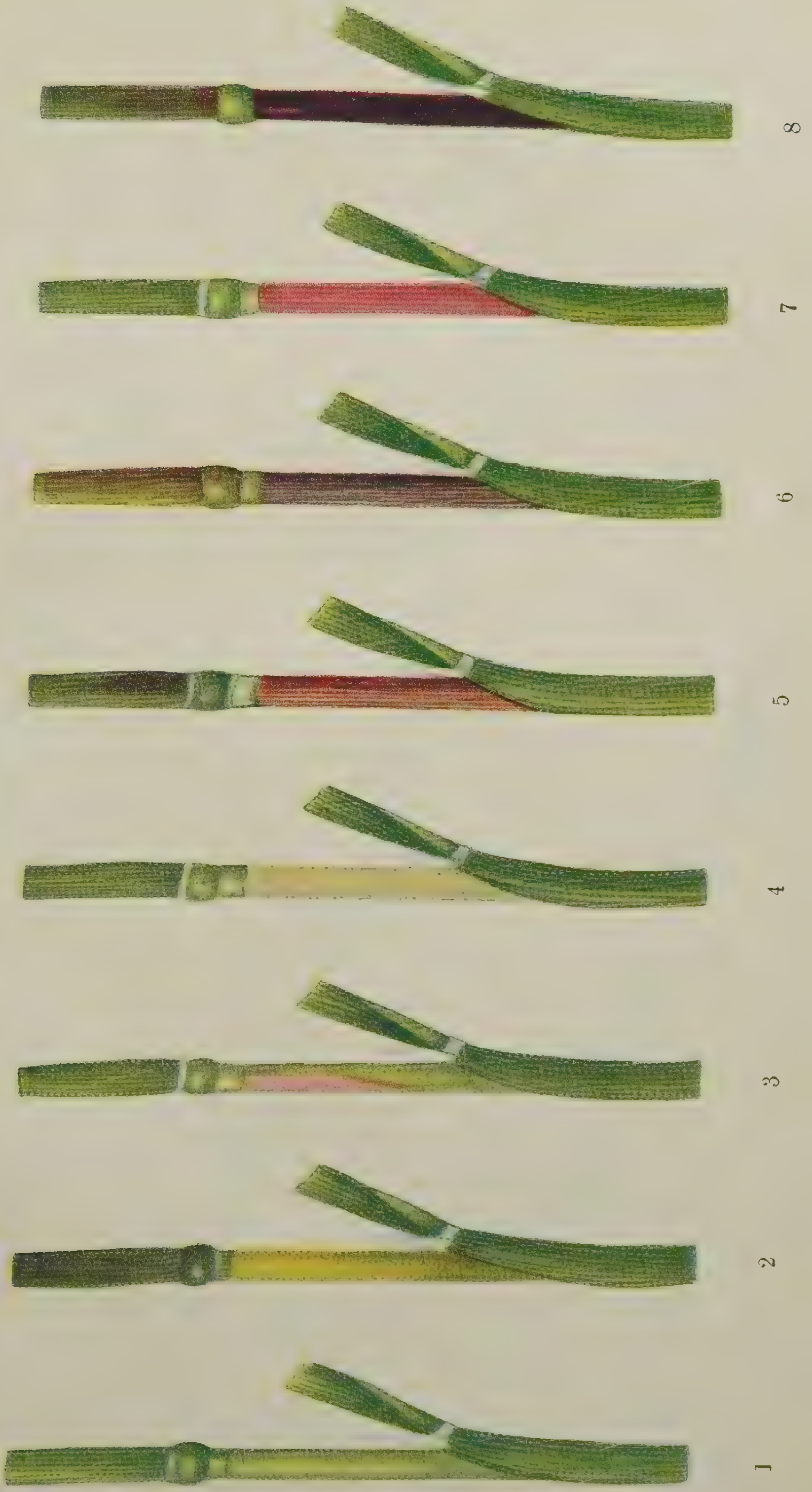
INTERNODE COLOURS



EXPLANATION OF PLATE XL

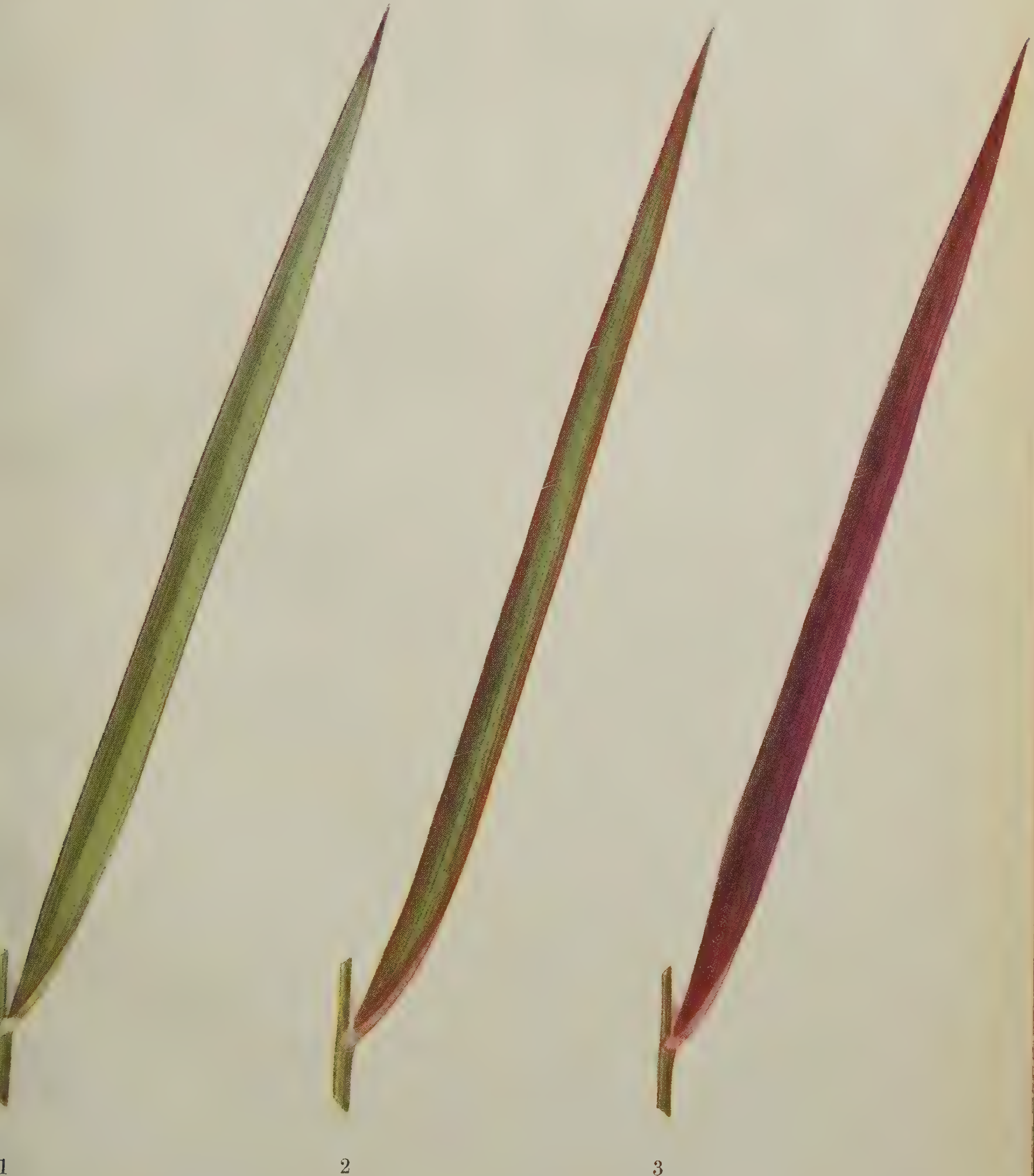
Internode colours

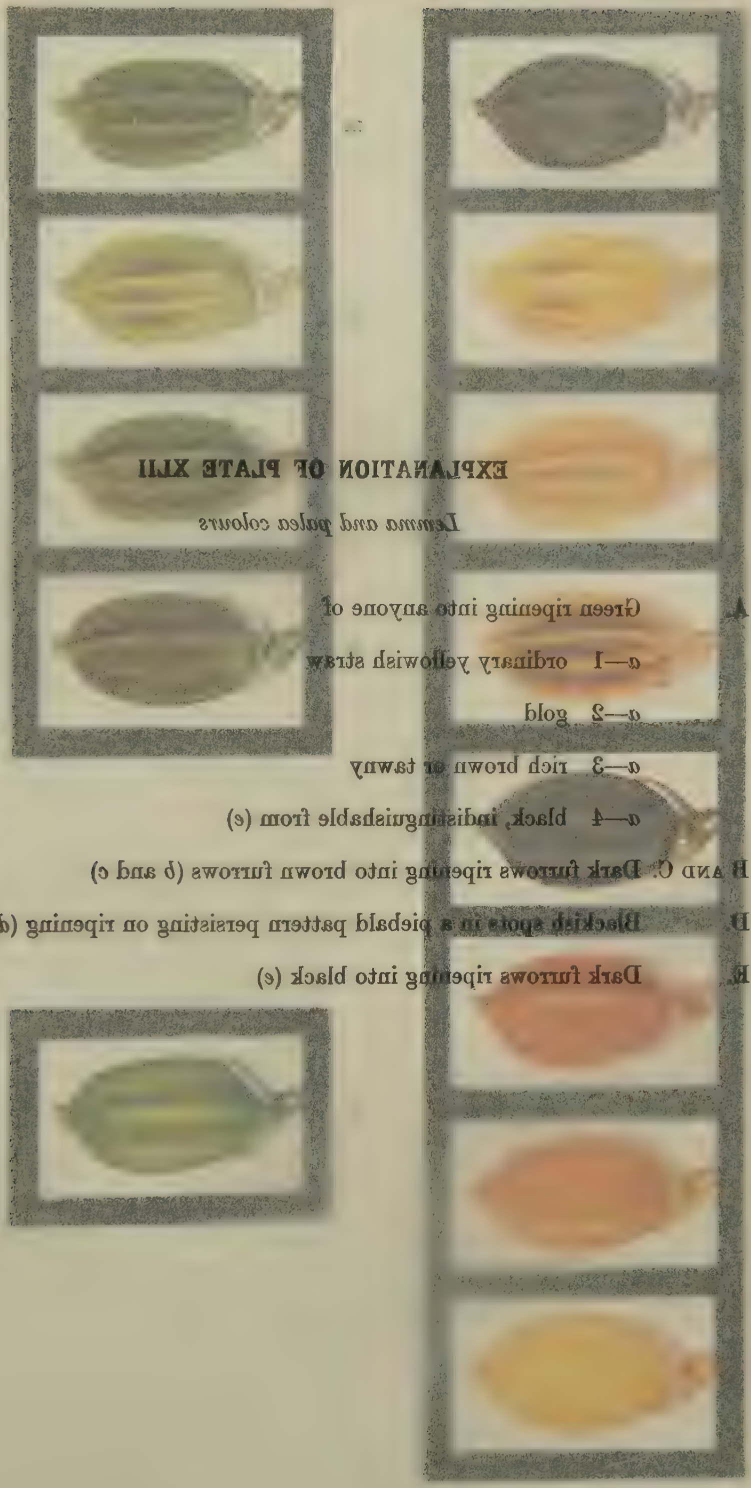
1. Green, no anthocyanin pigment
2. Gold or yellow, no anthocyanin pigment
3. Light purple lines (vascular bundles) showing only in the portions exposed to light
4. Light purple lines
5. Purple lines
6. Dark purple, lines almost black alternating with lighter ones
7. Purple all over, darker in the vascular bundles and lighter in the tissue between
8. Dark purple all over, looking almost black



INTERNODE COLOURS

LEAF BLADES





EXPLANATION OF PLATE XLII

Lemma and palea colours

A. Green ripening into anyone of

  a—1 ordinary yellowish straw

  a—2 gold

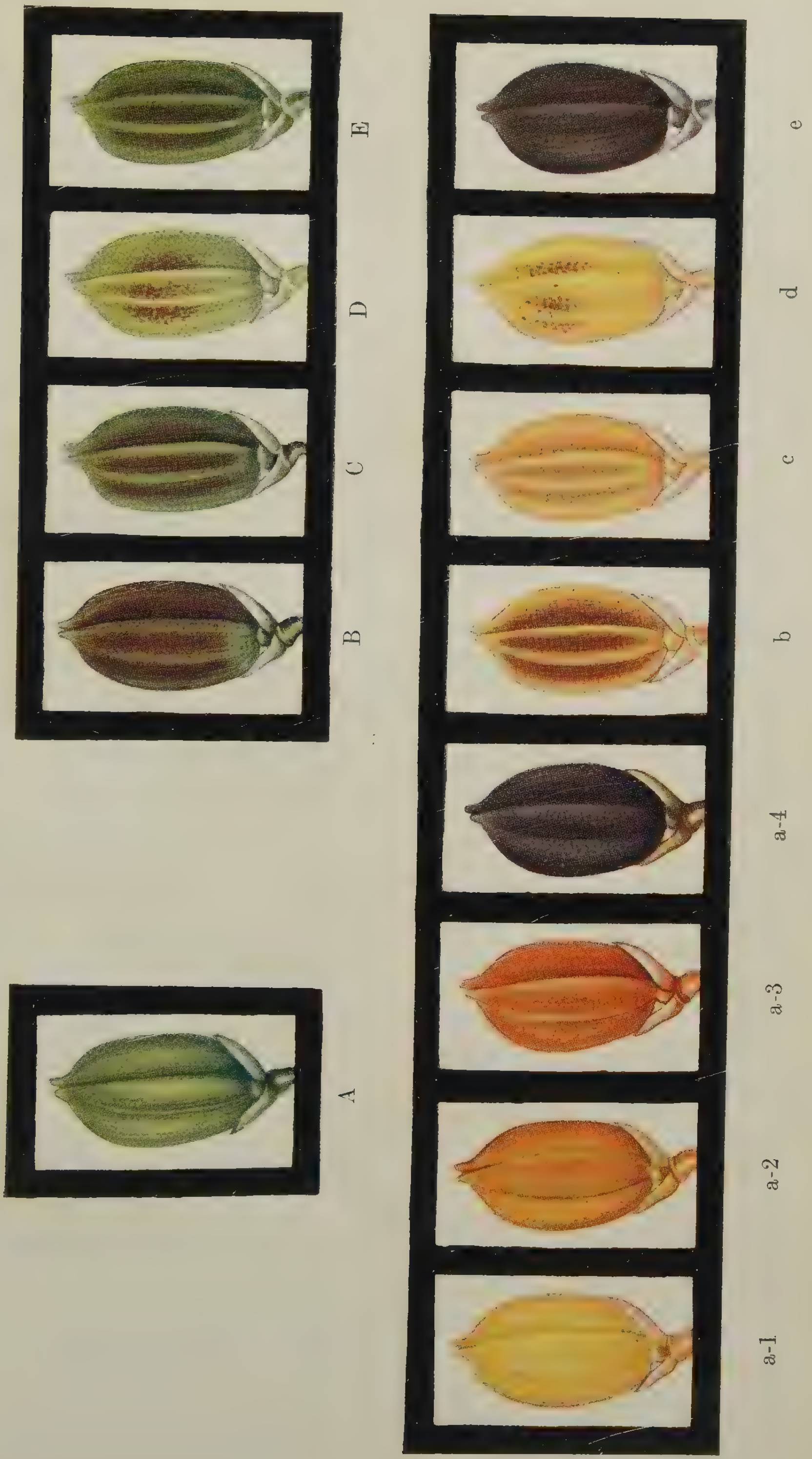
  a—3 rich brown or tawny

  a—4 black, indistinguishable from (*e*)

B AND C. Dark furrows ripening into brown furrows (*b* and *c*)

D. Blackish spots in a piebald pattern persisting on ripening (*d*)

E. Dark furrows ripening into black (*e*)


A
B
C
D
E
a-1
a-2
a-3
a-4
b
c
d
e

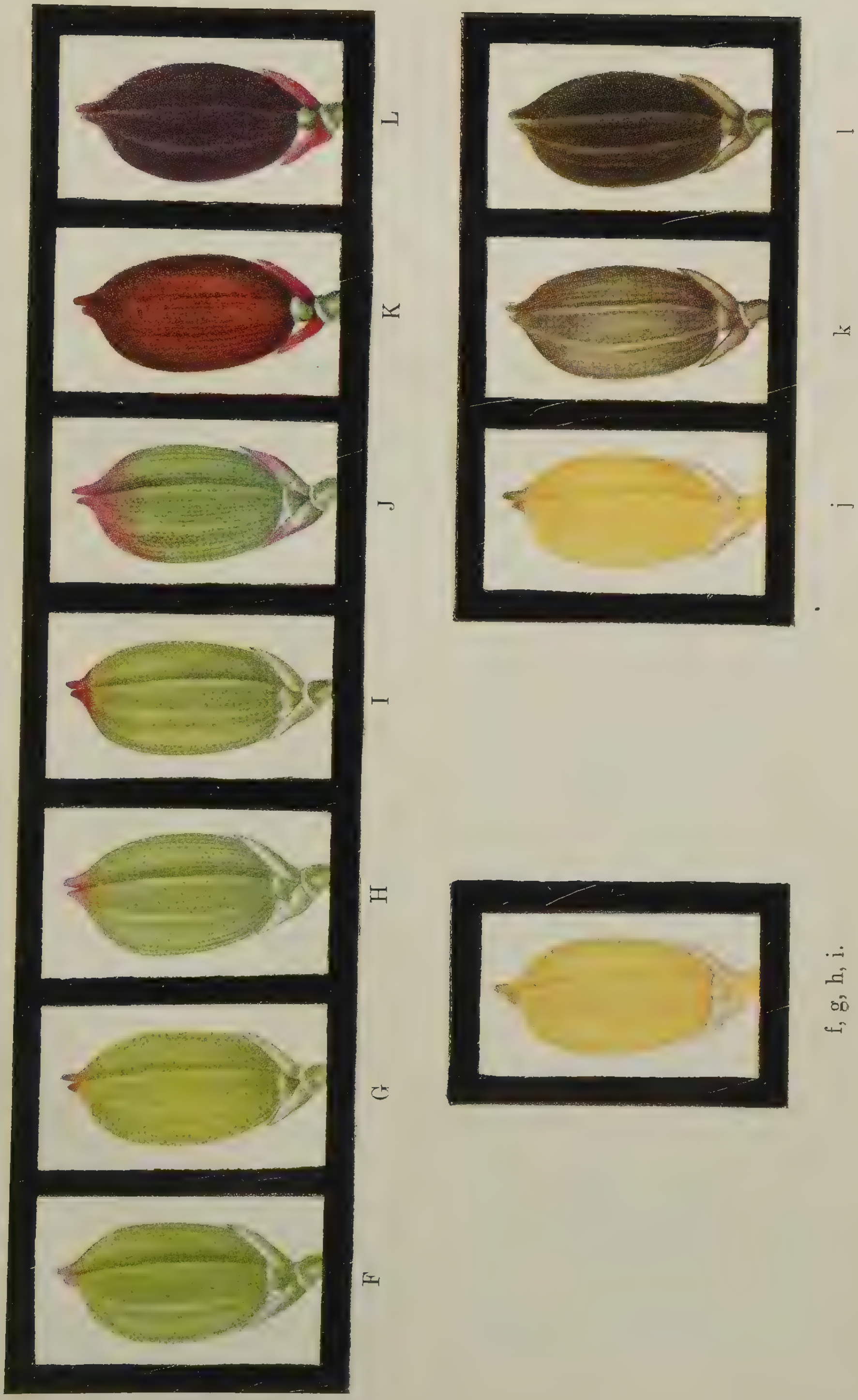
LEMMA AND PALEA COLOURS

EXPLANATION OF PLATE XLIII

Lemma and palea colours

F and G.	Green with purple apiculus, G being darker than F
H and I.	Green with purple spreading down slightly from the apiculus, I being darker than H
	All four are indistinguishable in the ripe stage
J.	Purple spreads much more in lemma and palea, the purple disappearing on ripening except in the apiculus
K and L.	Full purple lemma and palea, L being darker (almost black) than K, ripening into blackish brown k and l.

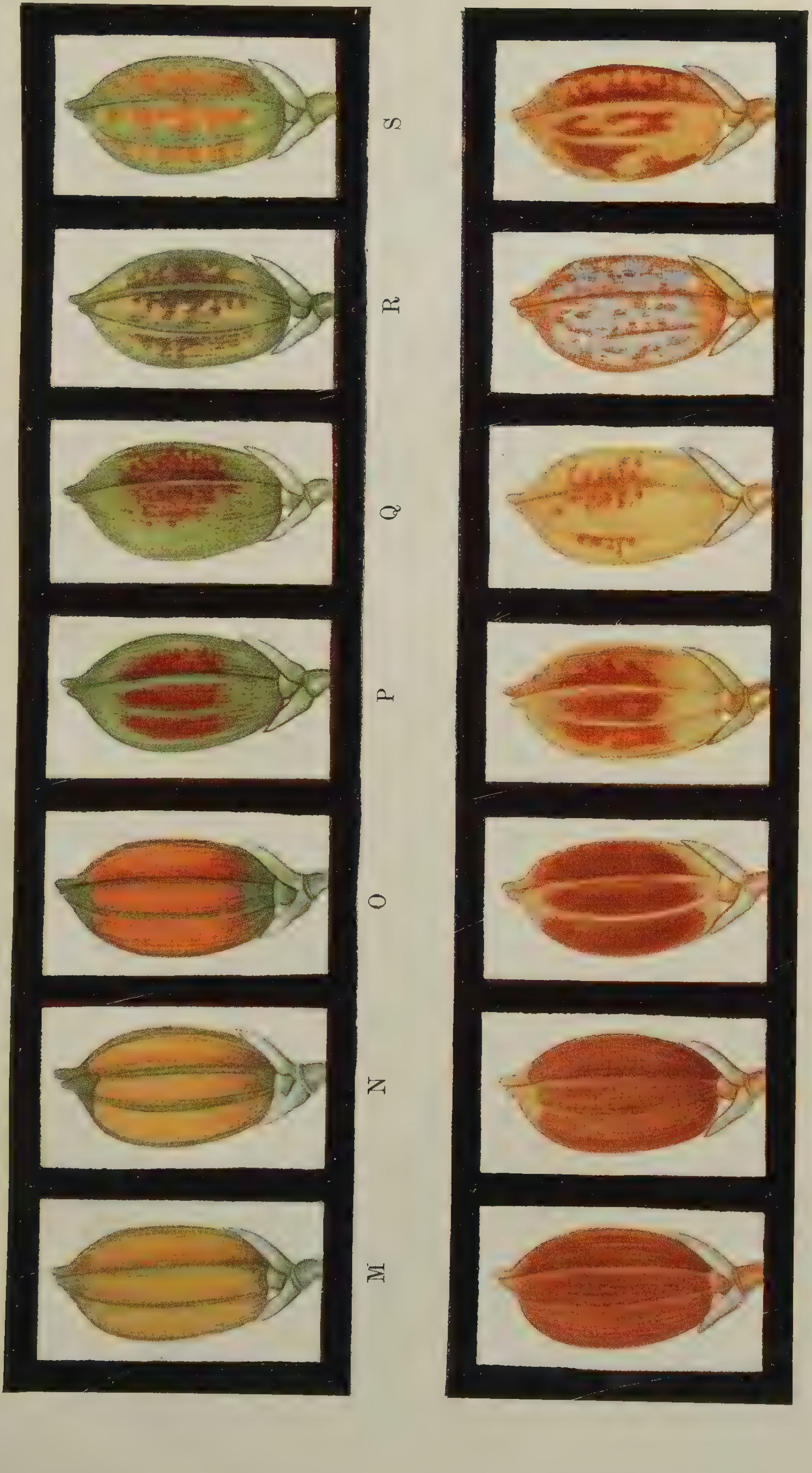
LEMMA AND PALEA COLOURS


L
K
J
I
H
G
F
l
k
j
f, g, h, i.

EXPLANATION OF PLATE XLIV

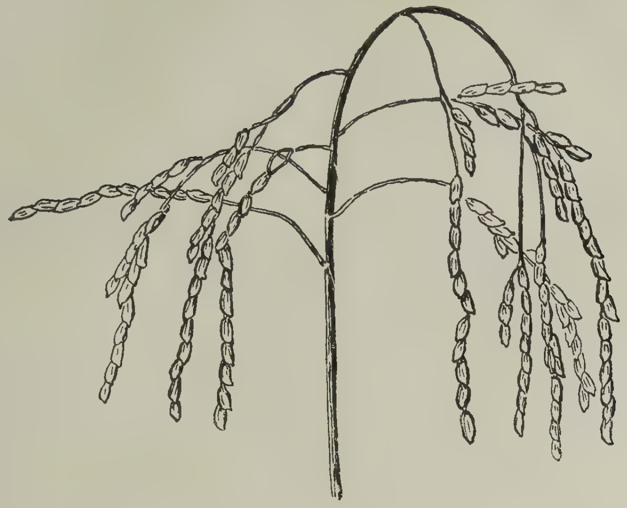
Lemma and palea colours

M — Q.	The gold or reddish orange colour varies in the green stage both in intensity and pattern of distribution on the lemma and palea while in the ripe stage (m – q) the colour all becomes reddish brown varying only in distribution
R.	Mottled green, the dark irregular patches becoming ashy coloured in the ripe stage on a brown background (r)
S.	Mottled gold or orange when young the distribution being same as in R the patches becoming darker on ripening (s)

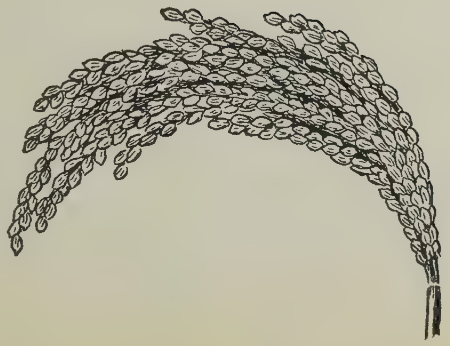

M
N
O
P
Q
R
S
m
n
o
p
q
r
s

LEMMA AND PALEA COLOURS

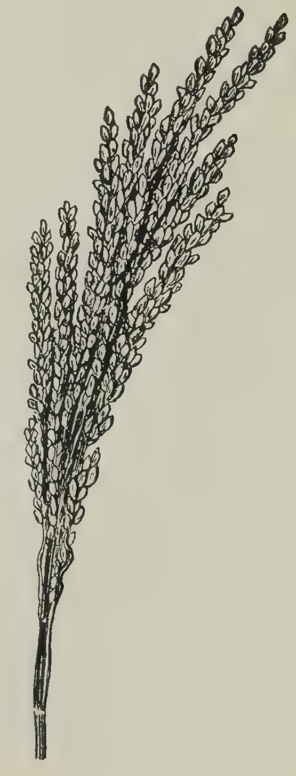
SHAPE OF PANICLE



1. Open

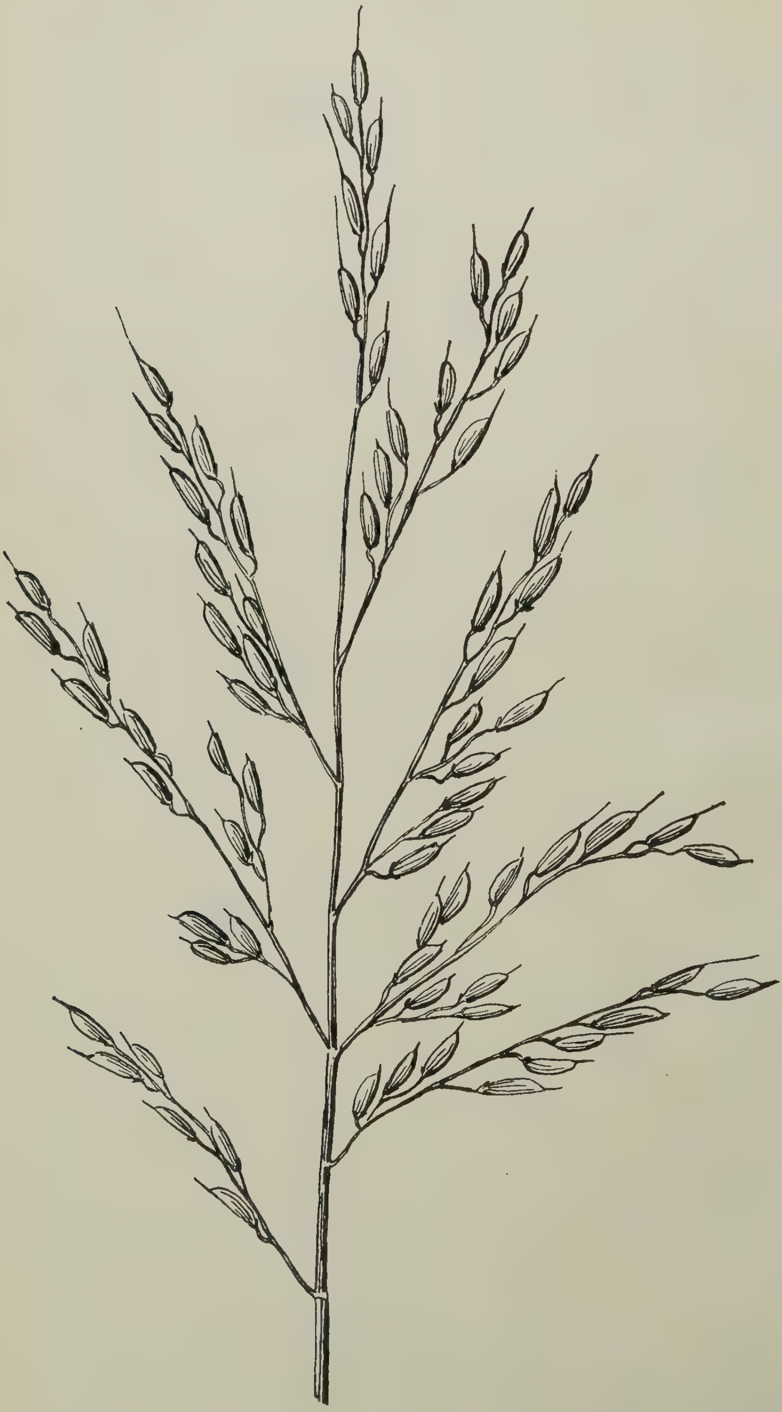


2. Compact and dropping

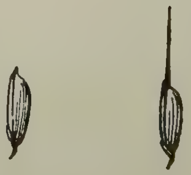


3. Compact and erect

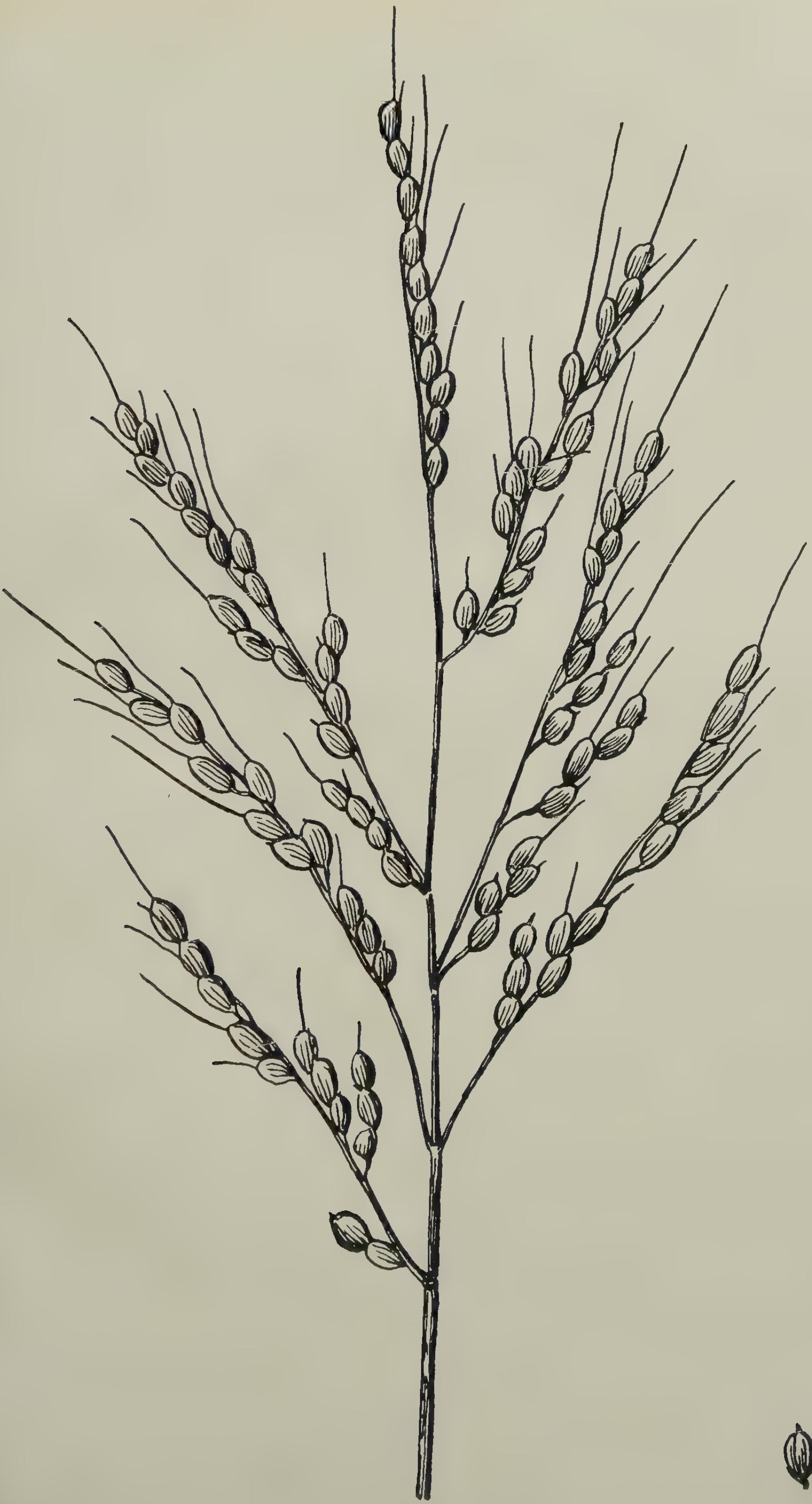
AWNS



Tipped



AWNS



Awned

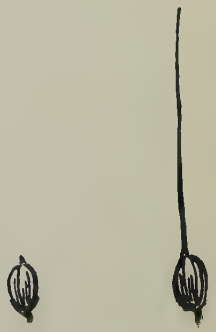
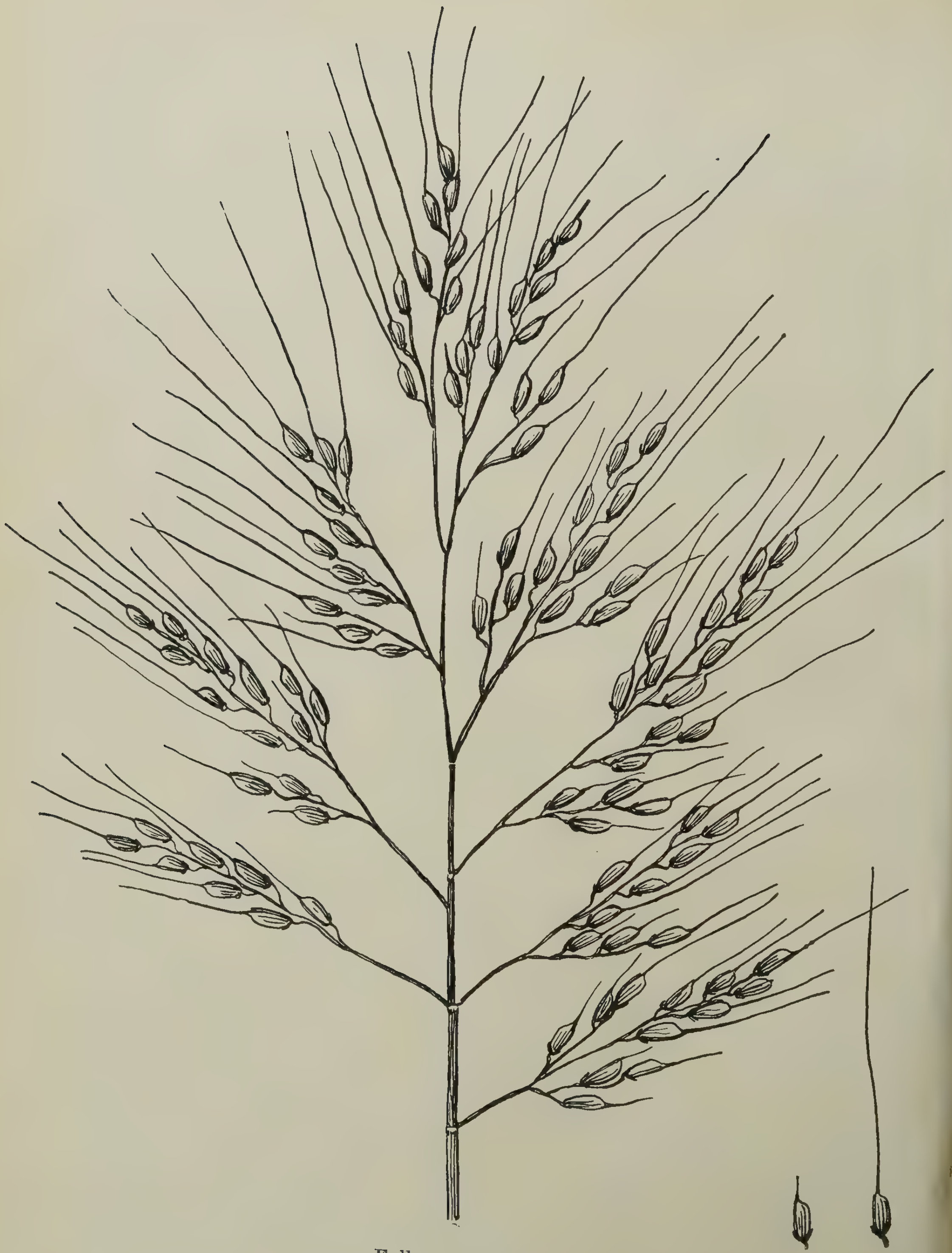
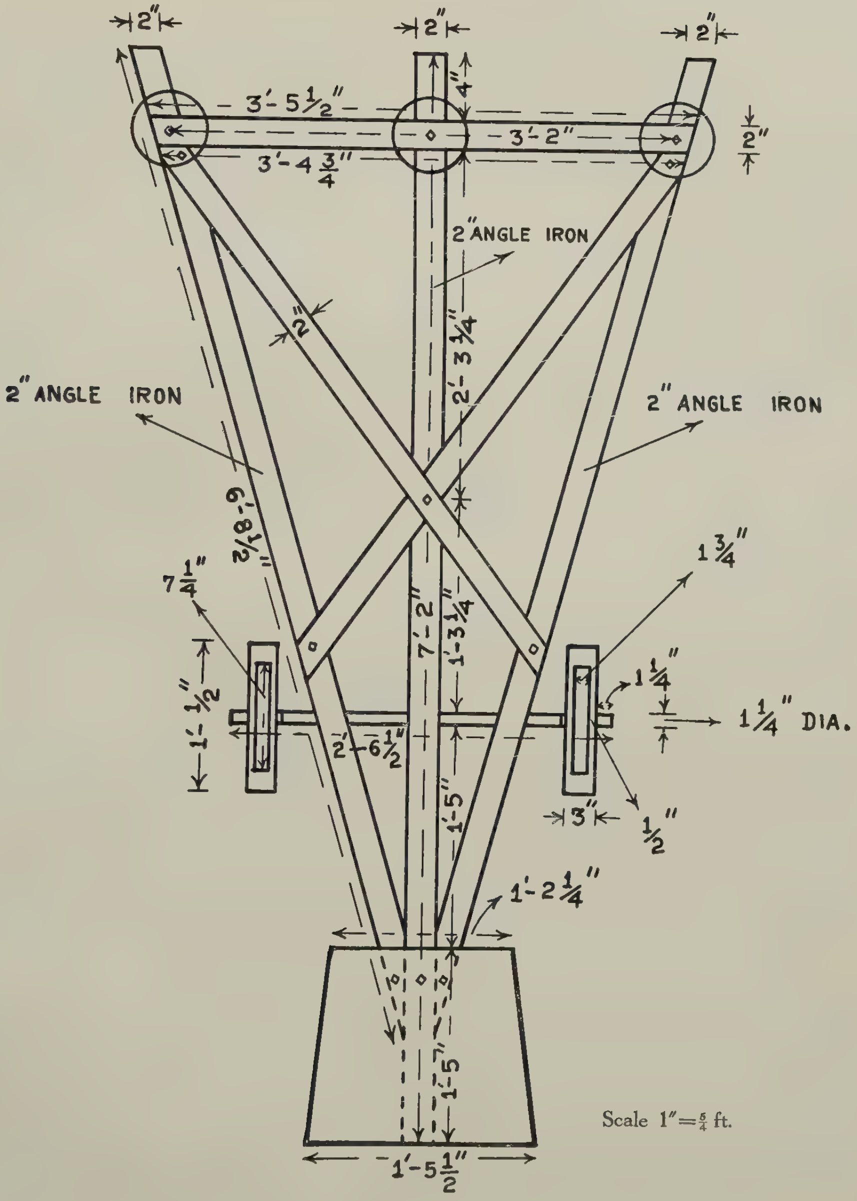


PLATE L

AWNS

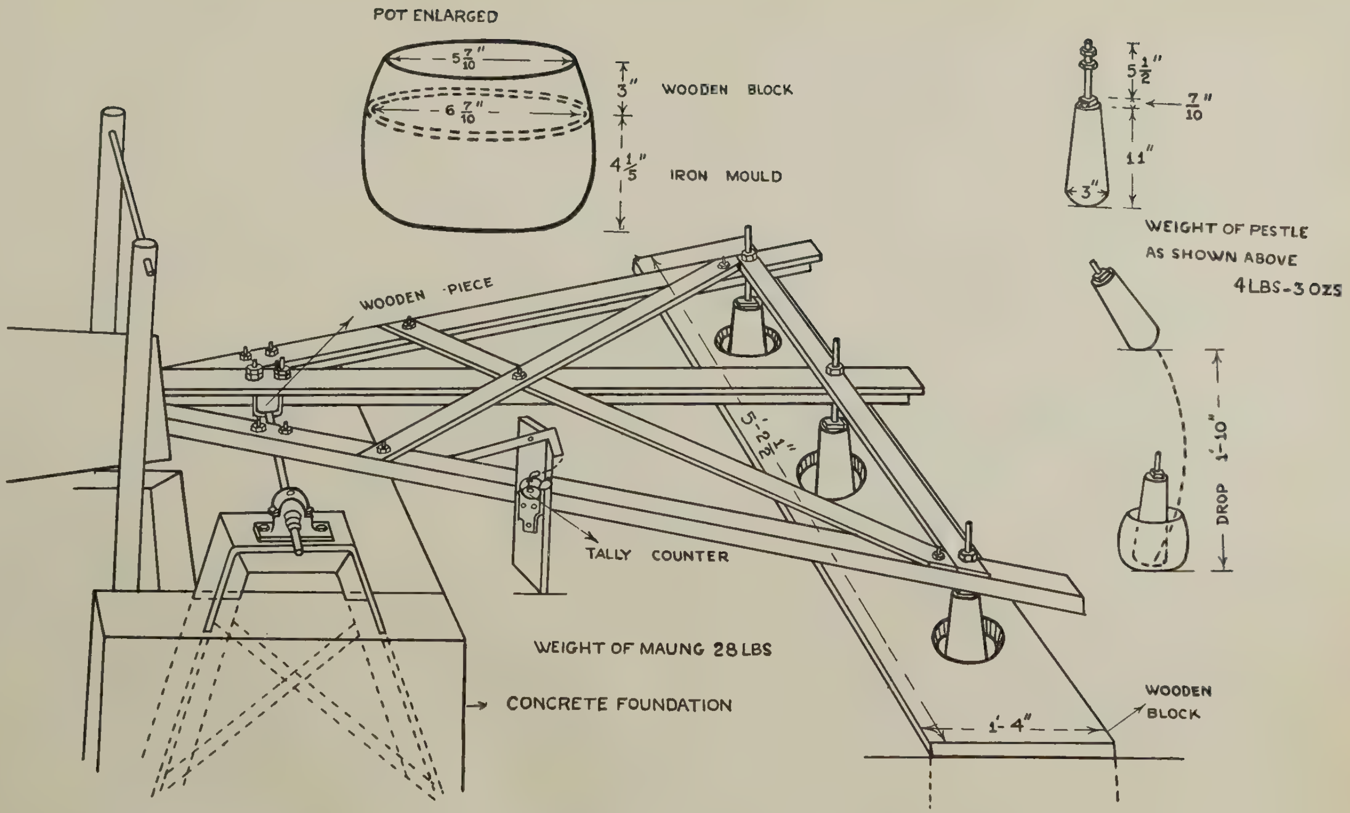


Fully awned


2"
2"
2"
3'-5½"
3'-2"
3'-4¾"
4"
2"
2" ANGLE IRON
2"
2'-3¼"
2" ANGLE IRON
2" ANGLE IRON
6'-8½"
7¼"
1¾"
7'-2"
1'-3¼"
1¼"
1'-1½"
2'-6½"
1¼" DIA.
1'-5"
3"
½"
1'-2¼"
1'-5"
1'-5½"

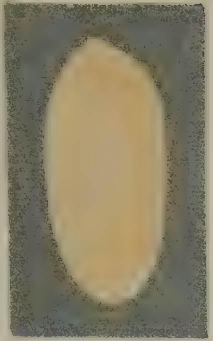
Scale 1″=5/4 ft.

Burmese Maung

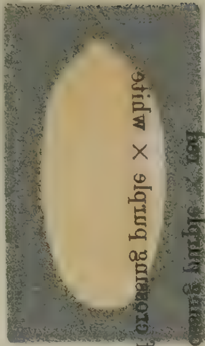

POT ENLARGED
5 7/10"
6 7/10"
3"
WOODEN BLOCK
4 1/5"
IRON MOULD
5 1/2"
7/10"
11"
3"
WEIGHT OF PESTLE
AS SHOWN ABOVE
4LBS-3 OZS
DROP 1'-10"
WOODEN ·PIECE
5'-2 1/2"
TALLY COUNTER
WEIGHT OF MAUNG 28 LBS
CONCRETE FOUNDATION
WOODEN
BLOCK
1'-4"

Burmese Maung

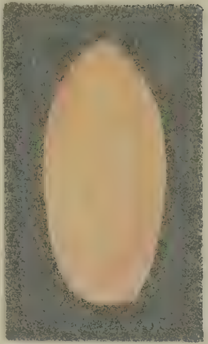
RICE COLOURS



1

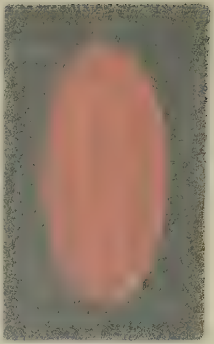


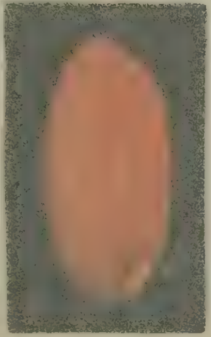
2



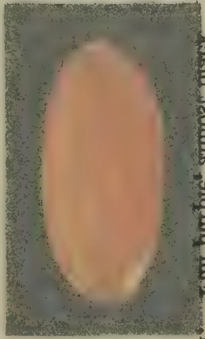
3

4

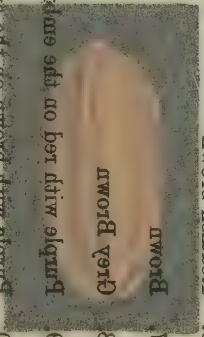




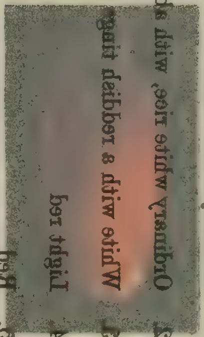
6



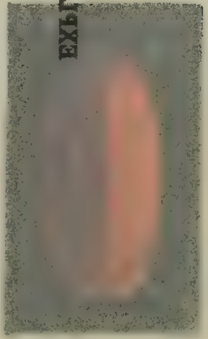
7

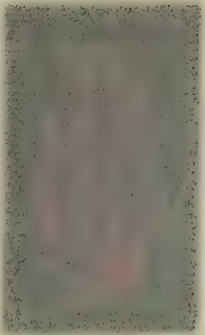


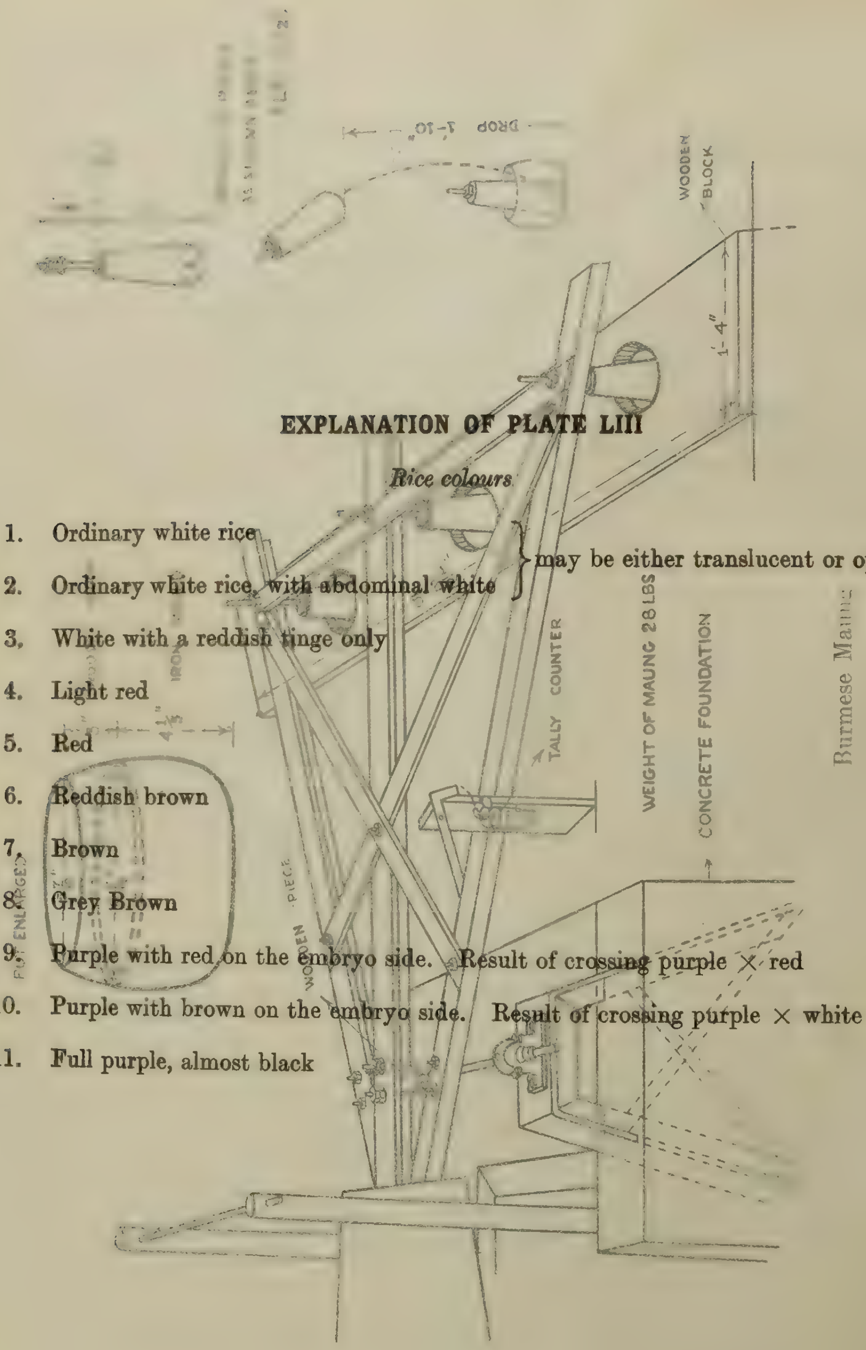
8



9






DROP 1'-10"
WOODEN BLOCK
1'-4"
IRON
4½"
TALLY COUNTER
WEIGHT OF MAUNG 28 LBS
CONCRETE FOUNDATION
WOODEN PIECE
ENLARGED

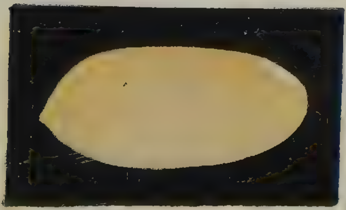
Burmese Maung

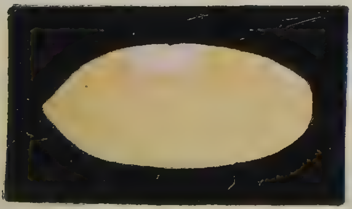
EXPLANATION OF PLATE LIII

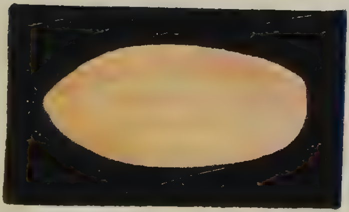
Rice colours

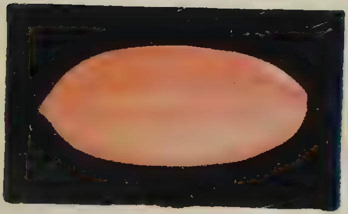
1. Ordinary white rice } may be either translucent or opaque
2. Ordinary white rice, with abdominal white } may be either translucent or opaque
3. White with a reddish tinge only
4. Light red
5. Red
6. Reddish brown
7. Brown
8. Grey Brown
9. Purple with red on the embryo side. Result of crossing purple × red
10. Purple with brown on the embryo side. Result of crossing purple × white
11. Full purple, almost black

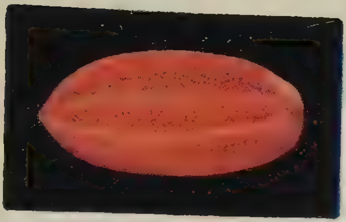
PLATE LIII

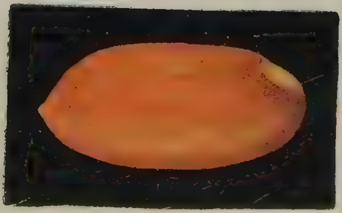

1

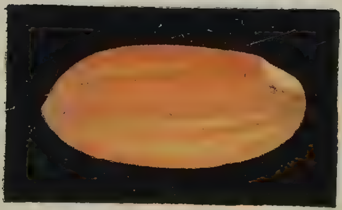

2

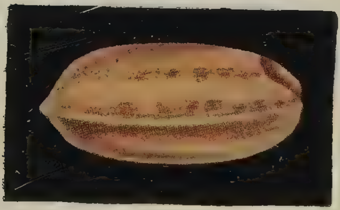

3

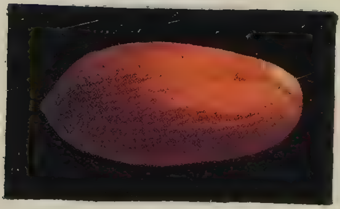

4

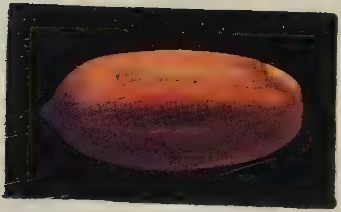

5

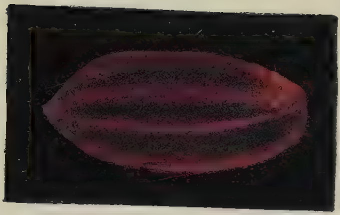

6


7


8


9


10


11

RICE COLOURS

HABIT OF THE COTTON PLANT AND ITS INFLUENCE ON OPTIMUM DATE OF APPLICATION OF NITROGENOUS FERTILIZER

BY

FRANK CROWTHER, D.Sc., A.R.C.S., D.I.C.
Imperial Chemical Industries (India), Ltd., Calcutta

(Received for publication on 27th June 1938)

(With three text-figures)

It is impossible to make a comprehensive statement for the Indian cotton crop about the best date to apply nitrogenous fertilizers for maximum yield increase, because, in the first place, the commercial crop comprises many different types of plant. Gammie's [1905] classification gives nine species for the Indian crop, that of Hutchinson and Ghose [1937] three, of which two are divided into three types. By contrast the Egyptian crop, for example, consists of only a single species. This specific complexity is further confounded by other differences. There is wide variation in soil types which range from the heavy black cotton soils of Central and Southern India to the light alluvial soils of the Punjab and the United Provinces ; and, though the bulk of the crop is grown on rain, much of the cotton of superior quality is dependent on artificial irrigation. Moreover, whereas in Sind the sowing date is April, in Surat it is June, and in South India, where it is grown as a winter crop, October.

At first sight the only way out of the maze seems to be by making in each district experiments which will cover all soil types, varieties and cultural methods—either by many single-factor trials or preferably by fewer multiple-factor experiments. But for a crop covering twenty-five million acres this would be a formidable undertaking, even if the combined resources of all the research bodies throughout India could be harnessed, and if cotton were the only crop of importance.

What then is the alternative ? One short-cut is suggested by the apparent relationship between the morphological habit of the plant and the crop's behaviour towards manuring. A study of the different habits of the various cotton species, as bound up with the sequence of changes occurring within the plant following extra nutrient absorption, gives indications of the probable time of application optimal for the different species. These indications can then be tested by experiment under given sets of conditions and, if confirmed, considerable information has been gained with a minimum of experimental work.

Date of application has already been tested by critical experiment in the Punjab and the results can be compared with those of Egypt and the Sudan—countries familiar to the writer where numerous experiments have been carried out. In the Punjab the results of Afzal [1936] and unpublished results of Imperial Chemical Industries (India), Ltd., all with ammonium sulphate, show the optimum date of application as around September 1st. The crop is sown in May and picked November-January and thus the fertilizer is applied to the crop after half the growing season has elapsed, *i.e.*, at the onset of flowering. It would naturally be expected that maximum benefit would accrue from a given amount of fertilizer when the period of absorption was longest, *i.e.*, when applications were made at sowing. This assumption has proved true for the Sudan Gezira Scheme where experiments have demonstrated an optimum date before sowing. In Egypt the optimum date is intermediate between those of the Punjab and the Sudan, an application shortly after sowing proving most efficacious.

MANNER OF THE PLANT'S RESPONSE TO INCREASED NITROGEN SUPPLY

There is reason to believe that differences as marked as those between the Punjab and the Sudan occur within India itself, and to understand them it is necessary to appreciate the changes which occur within the cotton plant following an increase in soil nitrogen supply.

The works of Gregory [1926, 1928], Maskell [1930], Mason [1930, 1934], Phillis [1937] and others have added greatly to the knowledge of the movement of nutrient supplies within the plant, their ascent into the leaves first, and the subsequent migration of synthesized materials to the reproductive parts.

When similar plants are compared under typical field conditions such as exist in India, some treated with ammonium sulphate and others untreated, laboratory examination reveals first of all a higher proportion of nitrogen in the leaf dry-matter of the treated plants. This is followed by a heavier total leaf-weight and greater carbohydrate synthesis of the plant. When the plants reach the fruiting stage, the young fruits also show higher values for percentage nitrogen and, as the increased supplies of nitrogen and the resulting carbohydrates accumulate, their migration to the fruits proceeds more rapidly, a greater number of fruits is produced and, to a less extent, the individual bolls grow bigger. Thus manuring results in more, and often larger, bolls and consequently in extra final yield.

The important point for date of application is that the nitrogen does not move straight from root to boll, but must travel *via* the leaf. Thus there is a time lag between application and the resulting increase in fruits while the extra foliar growth proceeds. The extra leaves develop after an interval, the exact duration of which is determined by local factors of soil and climate, and after a further interval come the fruits. Thus for a particular set of conditions an application of fertilizer means extra leaves at a fixed time and, provided the season is long enough, extra fruit also at a fixed time, and date of application is important because it ordains the time when the increased fruiting shall result.

It will be seen then that it is useless for the cultivator to apply his fertilizer late in the season so that it shall go direct to the bolls and not to extra leaf. Fertilizers are sometimes accused of producing merely extra leaf when in reality the extra bolls from early applications have been lost during early fruit-shedding. The late date of application established experimentally for the Punjab is the outcome of flower-shedding arising from the non-dehiscence of the anthers (see later).

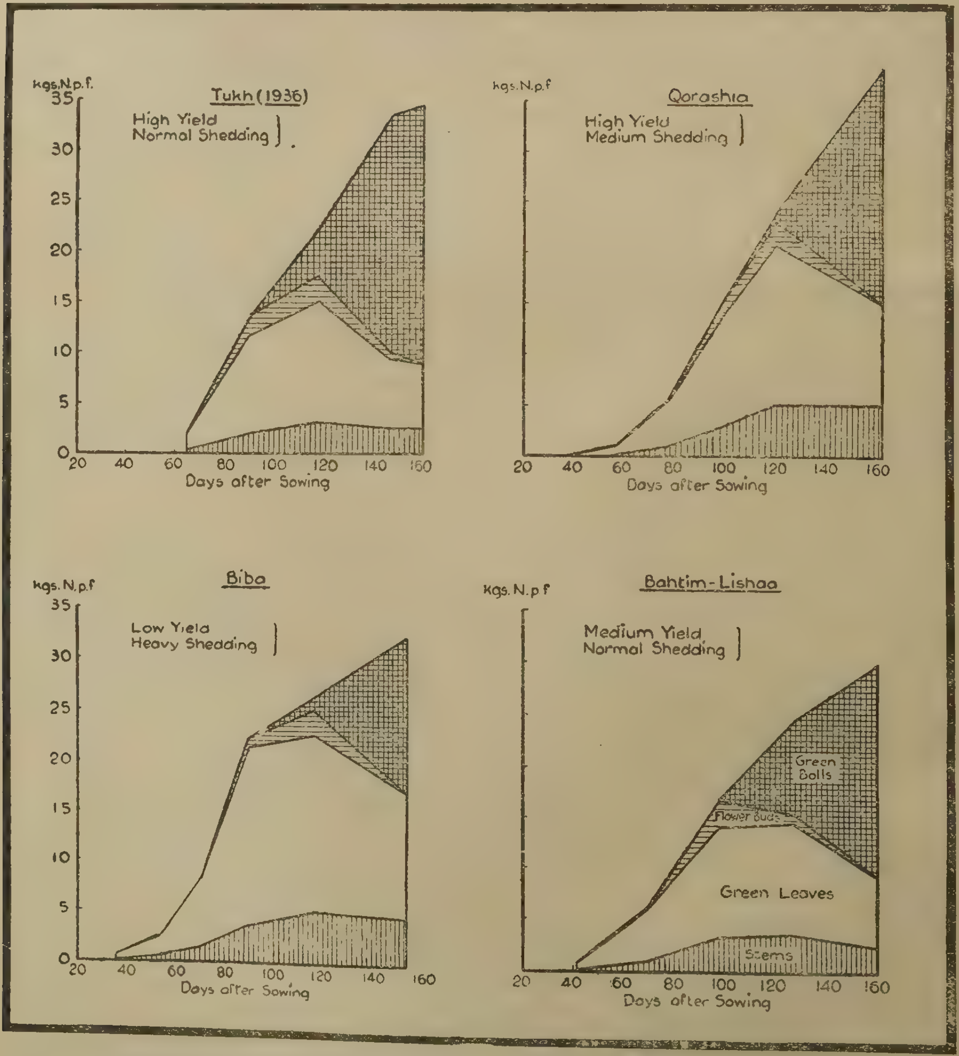
Reverting to the consideration of the movements of nitrogen within the plant, the initial supply of nitrogen (and other nutrients) for the very young plant lies in the seed, and very soon this is augmented by root absorption from the soil. The rate of this absorption is limited chiefly by the total area of the absorbing system of the roots and the concentration of nutrients in the soil. If this concentration is high, an increased supply by manuring has no immediate effect on absorption which is already proceeding at its maximum rate—a situation rarely occurring in Indian soils where the initial concentration of nitrogen is usually low. When the rate of absorption of unmanured cotton falls below the maximum, the treated plots begin to show a higher rate of absorption than the untreated, and the lower the initial supply of soil nitrogen, the greater will be the superiority of the manured plots.

The absorbed nitrogen accumulates in the leaves and growing points of the stem until fruit formation initiates migration from the leaves to the reproductive parts. This is illustrated in Fig. 1* by data from cotton in Egypt. The distribution of nitrogen among the various aerial parts of the plant—stem, leaf, flower-buds and bolls—is presented for successive stages of development for crops at four different sites. The curves for Tukh and Bahtim-Lishaa may be considered typical respectively of rich soil and soil of medium fertility both, where fruit-shedding is light. In these experiments migration to the bolls started about seventy days after sowing. Once started, this migration proceeded more and more rapidly until a large proportion of both nitrogen and carbohydrates had accumulated in the fruits. By commencement of picking (160 days after sowing) two-thirds of the total nitrogen of the aerial parts of the plant was concentrated in the fruits. This concentration is only achieved at the cost of nitrogen composition of the leaves, for the rate of migration outstrips the rate of entry of nitrogen into the leaves, the resulting leaf deficiency frequently leading to cessation of vegetative growth. This check to leaf development Gregory [1928] has termed ‘ internal starvation ’, and through its operation the leaves may be suffering nitrogen deficiency, while the roots are surrounded by plentiful supplies of nitrogen. The time of onset of ‘ internal starvation ’ and its severity are determined by the fruiting habit of the plant as influenced by local external factors. Fruiting, which begins early, while leaf development is still small, and proceeds at a rapid rate, will impose a check on vegetative growth early in the plant's development, for the demands of the fruit are great in proportion to the total food supplies within the plant. Thus acute

---

* This and Fig 2 are reproduced from the *Royal Agricultural Society* (*Egypt*) *Bulletin No. 31* (by F. Crowther).

'internal starvation' is characteristic of early-maturing varieties whose bolls form in a sudden flush. Where boll-formation proceeds gradually or where early fruits are shed, the period of vegetative growth is prolonged and the proportion of the total nitrogen of the plant concentrated in the bolls is much less (see the curves for Biba and Qorashia in Fig. 1). Here migration to the fruits was not considerable until ninety days after sowing, *i.e.*, about three weeks later than normal, and the delayed migration was associated with greater leaf activity.



IG. 1. Distribution of nitrogen within the plant (on plots) (kgs. N per feddon)

Fig. 2 shows that at Biba the delayed migration was the direct result of fruit-shedding in the young plants. The distribution of fruits up the main stem is shown diagrammatically by grouping them in numbers of bolls per zone of five nodes, nodes 6-10 being named A, 11-15, B and so on. Since the yield of cotton, unlike that of cereals, is built up over a period of time, this distribution furnishes a rough time-scale of crop arrival, the lowest bolls being the first to form and to open. Maximum production per zone was estimated by determining the total number of nodes on the sympodial branches, the intermediate and final stages by direct counts of fruits present on the day of observation. All three experiments in Fig. 2 enjoyed considerable early fruiting, *i.e.*, zones A and B, but the survival at Biba was less than a quarter that at other experiments, so that at Biba D zone near the top of the plant, and not B zone, supported the heaviest crop.

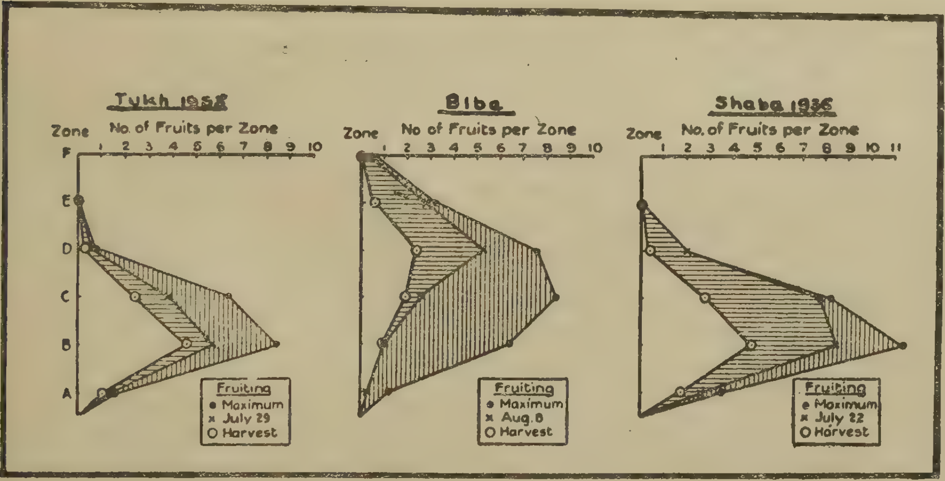


Fig. 2. Fruit shedding and survival (on plots)

Since the shedding of early-formed fruit slows down the rate of migration of nitrogen to the bolls and prevents 'internal starvation', it is clear that the position up the main stem of those bolls which eventually constitute the final crop determines the behaviour of the plant in nutrient absorption and fertilizer utilization. This position may be gathered from a study of the morphological habit of the particular variety and the modifications of this habit imposed by the influence of local factors, *viz.*, soil and climate.

The common commercial cottons of India are now reviewed for the effects of, first, variety and secondly, local factors, on the distribution of crop up the main stem, and this distribution is used as a guide to the probable stage of crop development at which to apply fertilizer for maximum yields.

VARIETAL CHARACTERISTICS AS A GUIDE TO DATE OF FERTILIZER APPLICATION

A varietal characteristic of cotton which bears intimately on fertilizer efficacy is the relative number and position of the sympodia (fruiting branches), whether they occur on the main stem or on monopodia (vegetative branches), for it is this which governs the rate of crop arrival. An attempt is made in Fig. 3 to show diagrammatically the principal varietal differences in branch development. Three contrasted indigenous cottons, four American types and a typical Egyptian variety are illustrated, and the branching is shown as it exists under field conditions where the rigours of competition have full play, not as in the taxonomical descriptions of variety given by plant breeders, which describe the 'ideal' plant growing without restriction.

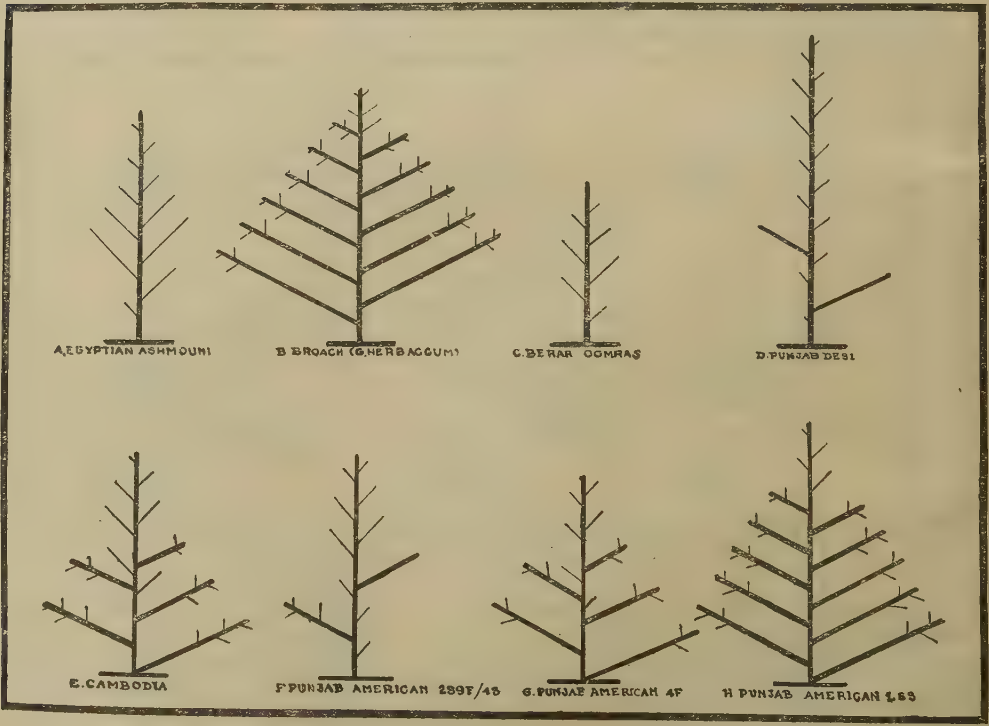


FIG. 3. Fruiting habit of different cottons (very diagrammatic)

The Egyptian plant (Fig. 3A) which formed the basis of the observations in Figs. 1 and 2 is considered first. Here there is an almost total absence of effective monopodia, field counts showing that mature fruits borne on monopodia represent less than 2 per cent of the total crop. The sympodia growing up the main stem are all-important for yield and they occur from the 8th or 9th node upwards, and bear a maximum of fruit about the 15th node. The plant is not tall and fruits rarely mature above the 27th node. This is an early-fruiting type of plant, and fertilizers are utilized most effectively when applied early, *i.e.*, at sowing or shortly afterwards.

The plant in India which resembles most the Egyptian type in branching habit is that constituting the commercial 'Oomras' crop (*G. neglectum*) of Berar, Central Provinces and Khandesh (Fig. 3C). Here growth is unusually stunted from insufficient moisture—the plants rarely meet across the rows and the main stem attains a maximum height of 1½ to 2 feet. Monopodia are unimportant for yield; sympodia are formed low down the main stem, and fruiting is abundant on these lower branches. The crop is thus an early one, having a short growing season and the bolls appearing in a rapid flush. These characteristics point to an early application of fertilizer, and, apart from effects of rainfall distribution, applications at, or even before, sowing should prove optimal.

Punjab-*desi* (Fig. 3D) (*G. indicum mollisoni*) resembles the above in scarcity of monopodia but the node development of the main stem is much greater, especially under artificial irrigation, and the final height is usually 3 to 4 feet. Sympodia occur at intervals from the 10th or 12th node upwards, but the extent of their development is more restricted than in the Berar type. Thus, apart from fruit-shedding, the bolls arrive early but not in such a rapid flush. Because of the restricted branching the cultivator at thinning leaves the *desi* plants at a close stand which accentuates the need for early application of at least some of the fertilizer. The absence of a flush of bolls averts an onset of 'internal starvation' comparable in severity with that in the Egyptian plant (Fig. 3A), and if the two were grown under similar field conditions the *desi* plant would probably be the less responsive to nitrogen. Moreover, since the lower crop constitutes only a small proportion of the whole there is need for a later application. Here then is a plant which would seem to require a split fertilizer application, one dose near sowing time and another dose or two later. But, in the Punjab, a local factor, *viz.*, excessive fruit-shedding upsets this economy, for much of the lower crop fails to reach maturity (see later).

The *herbaceum* species (Fig. 3B) which typifies the bulk of the commercial crop of Lower Gujerat, Karnatak and North Madras provides the greatest contrast in India to the Egyptian type (Fig. 3A). The plant has numerous monopodia, extensively developed and themselves bearing sympodia which contribute largely to the final crop. There is a marked absence of productive sympodia on the lower part of the main stem and a consequent lack of early crop. The vegetative phase, not being subject to early curtailment through 'internal starvation', allows of, not only abundant leaf growth but also deep and vigorous rooting, provided soil-moisture supply is sufficient It is improbable that the optimum date of application for *herbaceum* cotton is sharply defined, and it may well extend from shortly after sowing up to flowering time.

The American types (*G. hirsutum*) grown in India (Fig. 3E, F, G and H), while among themselves they do not show such a wide range in branching habit as between Berar Oomras and *herbaceum* show differences which are important if only because these cottons are likely to be manured on a commercial scale, since they are artificially irrigated and are of superior quality.

In Fig. 3 Cambodia and the three Punjab-American types, 289F/43, 4F and LSS are included. 289F/43 carries most of its crop on the main stem, the first sympodial branch occurring at the 7th or 8th node and the monopodia rarely numbering more than three. By contrast, LSS bears only a small part of its crop on the main stem, the numerous monopodia contributing largely to the final crop. The first sympodial branch rarely occurs below the 20th node. 4F is intermediate between the two, about half the crop growing on sympodia and half on monopodia, the first sympodial branch occurring at about the 15th node. Thus 289F/43 has most resemblance to the Egyptian and Berar types, but bears more upper crop. This suggests that 289F/43 has an early optimum date of application, whereas LSS benefits more than 289F/43 from later application and probably has no clearly defined optimum date. There is no reason to believe that a split application will be more effective than one dose, except possibly for LSS.

MODIFICATIONS INTRODUCED BY SOIL AND CLIMATE

Superimposed upon the influence of branching habit which is an inherited characteristic of the particular variety or strain are effects of the external factors of soil and climate. These are considered together since with present knowledge it is often difficult to distinguish where the influence of soil ends and that of climate begins.

The Sind and Punjab crops, both American and *desi*, suffer heavy early fruit-shedding. Since the crops are sown respectively in April and May, they should be ready for picking in August and September, instead of as in practice a month or two later. The early fruit-shedding of American types has been shown by Trought [1930] to arise primarily from non-dehiscence of the anthers, the consequent absence of pollination leading to flower-shedding. Later-opening flowers have normal anthers. *Desi* types show normal dehiscence, even early in the season, yet sustain some early fruit-shedding, which indicates that part of the loss of early fruit in the Punjab must be ascribed to some cause other than non-dehiscence of the anthers, probably water-strain arising out of the drying of the top soil between irrigations, combined with the very high maximum temperatures.

At harvest the crop of the Punjab and Sind American varieties is found to be distributed approximately like that of Biba in Fig. 2, where the presence of sympodia from the lower part upwards proves that an early crop has existed at least in the flower-bud stage. The shedding is so acute that the effective fruiting habit of the American type is transformed until LSS and 4F approximate to *herbaceum* in their behaviour.

Here then is a reason for the late optimum date in the Punjab already established by direct experiment, *viz.*, applications made in August or September to a May-sown crop. Earlier applications lead to extra leaf formation and fruiting, but the extra fruits from manuring are largely shed along with the rest of the crop and much of the benefit from manuring is lost. The latee the application, the less the effect of shedding, until a point is reached when the delay cuts down too drastically the interval before boll-opening.

The soil of the Punjab also favours a later application. Its clay content is low and artificial fertilizers are not retained near the surface as they are in heavier soils like those of Central India, but are partly washed down to lower depths. Early applications will then be leached past the root zone of the young plants. But it is unlikely that this washing down will seriously affect the general efficacy of fertilizers, because the Punjab cotton roots deeply—roots have been traced down to 18 feet by the Cotton Research Botanist at Lyallpur.

The combined effects of fruit-shedding, season duration and lightness of soil reveal an optimum around September 1st. Should the plant breeder, however, introduce a variety which resists shedding, the date of fertilizer application will have to be re-examined.

Since the Punjab-*desi* crop is less affected by early shedding than the American crop because the anthers open normally, the indications from branching habit are not so greatly modified by local conditions. Up to the present, experiments on date of fertilizer application have been made only on American cotton, but with *desi* it is probable that a split application, half soon after sowing and half at flowering will prove optimal.

The branching habit of *herbaceum* cotton suggests that fertilizer applications will give similar increases, whether applied early or late, for the crop is borne on the extremity of the main stem and on monopodia, and the season is a long one. Nevertheless in Surat late applications will gain a certain advantage because of some fruit shedding occasioned by Spotted Bollworm damage. But since *herbaceum* cottons are usually grown in districts where irrigation water is not available, adequate rainfall must be assured if late-applied fertilizer is to be thoroughly incorporated into the soil and if the leaf turgidity necessary for extra leaf development is to be maintained. Fortunately in the Surat tract, as the Agricultural Branch of the Meteorological Department at Poona has shown [1936], rainfall is less precarious than in other parts of Bombay or in Berar and the Central Provinces. For this reason fertilizer application may be delayed with greater safety in Surat than in the above regions, or for that matter in the Ceded Districts of Madras.

On the other hand, soil conditions suggest the importance of early applications. *Herbaceum* cottons are grown mostly on black cotton soil, *i.e.*, heavy clays. Because these soils are retentive of moisture they are capable of supporting a crop for a longer period than lighter soils, which permits greater nutrient recovery and soil exhaustion. Moreover the heaviness of the soil hampers root development and leads to greater concentration of roots in the surface soil. Exhaustion of the top soil therefore arises early in the plant's growth and, if a check to development is to be avoided, early applications would seem necessary.

Thus for *herbaceum* cottons a compromise is indicated, half the dose being applied early to redress soil exhaustion and half later to sustain the prolonged growth, the exact date of the second application to be determined by the probability of rain incidence.

The *neglectum* cottons of Berar, the Central Provinces and Khandesh are, like *herbaceum,* usually grown on heavy clay soil. There, soil conditions reiterate the need for an early application of the complete dressing, indicated by the plant's morphological characters. The unusually close spacing, often obtained by the omission of the thinning operation, and the uncertainty of rainfall also point in the same direction. The only circumstance, where any benefit will be derived from delaying the application till two or three weeks after sowing, is where the land is liable to flooding and erosion which will wash the fertilizer away to a lower part of the field—a purely surface effect.

The irrigated Cambodia crop of Madras does not suffer the same severe loss of early crop as its *hirsutum* relatives in North India and thus local factors do not modify the indications from its branching habit. The climate is less rigorous and the absence of cold weather checking and damaging late growth removes a restriction which elsewhere narrows down the optimum date of application by inhibiting late development. With Cambodia in Madras therefore the period over which similar optimal yield responses prevail is likely to be a comparatively long one, showing no sharp definition like that in the Punjab and Central India.

The Tinnevellies (mixed *G. indicum* and *herbaceum*) around Koilpatti suffer such profuse shedding of flower-buds—sometimes resulting in a 50 or 60 per cent fall in yield—if February rains are frequent [Madras Agriculture Department, 1937] that this shedding becomes the dominant factor determining date of fertilizer application. Such shedding cannot but interfere with the plant's internal economy of nitrogen and other nutrients. This February loss of fruit is comparable with the loss of early fruit in the Punjab, though it arises from a different cause. In both cases maximum returns from manuring are obtained only when the application is delayed so that the flush of extra fruit is timed to appear after the period of heavy shedding. Applictaions during late January or early February will not be far from optimal when considered over a period of years.

So far nothing has been said of the crop of the United Provinces (mixed *G. indicum* and *neglectum*). Its habit of growth has affinities with that of the Punjab *desi* but more crop is carried on monopodial branches. In the United Provinces the importance of morphological habit for date of fertilizer application is dwarfed by the incidence of Pink Bollworm which in a normal year destroys 25 per cent, and in some years up to 50 per cent of the later crop. With losses of this magnitude it is obvious that only early applications of fertilizer can be effective. Since fertilizer merely augments an existing supply of nitrogen in the soil, it begins to have effect only when the initial soil supply falls below the optimum for maintaining the maximum rate of uptake by the plant. Usually the first fruits are not dependent on the added supply.

Thus fertilizer avails only for later-formed fruits nearer the top of the plant, and, if applied late, will bring the extra crop into those zones where the loss from Pink Bollworm is most serious.

SUMMARY

The movement of nutrients within the plant following fertilizer application is described from experimental work in Egypt and elsewhere, and against this background the influence of the branching habit of the chief commercial varieties of India on the optimum date of application is discussed, with the modifications introduced by local influences of soil and climate.

The late date of application, *viz.*, during flowering, which has been established experimentally in the Punjab for irrigated American cotton is explained by modification of plant habit by excessive early fruit-shedding. The plant's morphological habit permits fruit production over a long period and suggests that the optimum date of application also extends over a period ; but, since chiefly by non-dehiscence of anthers the early fruits are largely shed, much of the benefit from early applications will be lost.

The branching habit of the commercial crop of Central India suggests applications at, or soon after, sowing and this is endorsed by the influences of soil and climate.

Herbaceum cottons with their long growing season and freedom from any marked check to development through 'internal starvation' suggest an application in two doses, one to encourage early vegetative growth and another later, according to rain incidence, to sustain the protracted growth and avoid the risk of reduced response through any early fruit-shedding which may occur.

In the United Provinces and the Koilpatti district of Madras the influence of local factors is paramount, the former suffering severe Pink Bollworm damage and the latter fruit-shedding after February rains. In both cases the date of application must be so timed that the extra bolls from manuring suffer minimum loss from these adverse factors.

ACKNOWLEDGMENT

The writer wishes to record his indebtedness to Mr. Mohammad Afzal, Cotton Research Botanist, Lyallpur, for furnishing information and useful criticism.

REFERENCES

Afzal, M. (1936). *Rept. on the Punjab Botanical Research Scheme of Cotton Research Botanist.*

Crowther, F. (1934). *Ann. Bot.* **48**, 877

——— (1936). *Bull. Roy. Agric. Soc.* (*Egypt*), No. **25**,

——— (1937). *Ibid.* No. **31**

Gammie, G. A. (1905). ' The Indian Cottons'. Govt. Press, Calcutta

Gregory, F. G. (1926). *Ann. Bot.* **40**, 1

——— (1928). *Rept. of Meeting of Research Workers held at Gezira Research Farm, Sudan Govt.*

Hutchinson, J. B. and Ghose, R. L. M. (1937). *Ind. J. Agric. Sci.* 7, 233

India Meteorological Dept. (1936). *Supplements to Rept. Agric. Meteor. Branch for* 1934-35, p. 11

Madras Agric. Dept. (1937). ' Popular Account of Progress of Work of Madras Agric. Dept. 1922-35 ', p. 43

Maskell, E. J. and Mason, T. G. (1930). *Ann. Bot.* **44**, 657

Mason, T. G. and Phillis, E. (1934). *Ann. Bot.* **48**, 315

Phillis, E. (1937). *Emp. Cotton Growing Rev.* **14**

Trought T. (1930). *Mem. Dept. Agric. Ind.* (*Bot. Ser.*) **17**, No. 6

A NOTE ON BORDER EFFECTS IN MANURIAL EXPERIMENTS ON COTTON AT SAKRAND DURING 1935-36

BY

B. M. DABRAL, M.Sc.

Cotton Physiologist

AND

S. S. CHINEY, B.Sc.

Statistical Assistant to the Cotton Physiologist, Agricultural Research Station, Sakrand (Sind)

(Received for publication on 18th October 1937)

(With one text-figure)

CONTENTS

	PAGE
INTRODUCTION	629
MATERIAL	630
RESULTS	631
STATISTICAL ANALYSIS	632
DISCUSSION	634
CONCLUSION	634
SUMMARY	634
ACKNOWLEDGMENTS	635
REFERENCES	635

INTRODUCTION

It is well known that border rows usually yield more per unit area than the inside rows [McClelland, 1929 ; 1934 ; Hollowell and Heusinkveld, 1933 ; Deming and Brewbaker, 1934]. Work on the border effects by Immer [1932], Justesen [1932] and Kalamkar [1932] has been summarised by Christidis [1935] who concluded that experiments should be laid out in such a manner as to make it possible to discard the border effects, as otherwise they may introduce bias in the results. Recently Hutchinson and Panse [1935] have studied the various components of border effects in detail. All these studies have been either on varietal or on uniformity trials. The effects of inclusion or otherwise of border rows in manurial experiments have not been studied so far, except by Coombs [1934], and the present paper is intended to deal with this aspect of the question.

MATERIAL

The present study is based on the results of manurial experiments conducted in cotton at the Agricultural Research Station, Sakrand, in 1935. The full agricultural details are given below :—

Agricultural details

1. *System of replications.*—6 × 6 randomised blocks.
2. *Area.*—The diagram below shows the areas for harvest :—

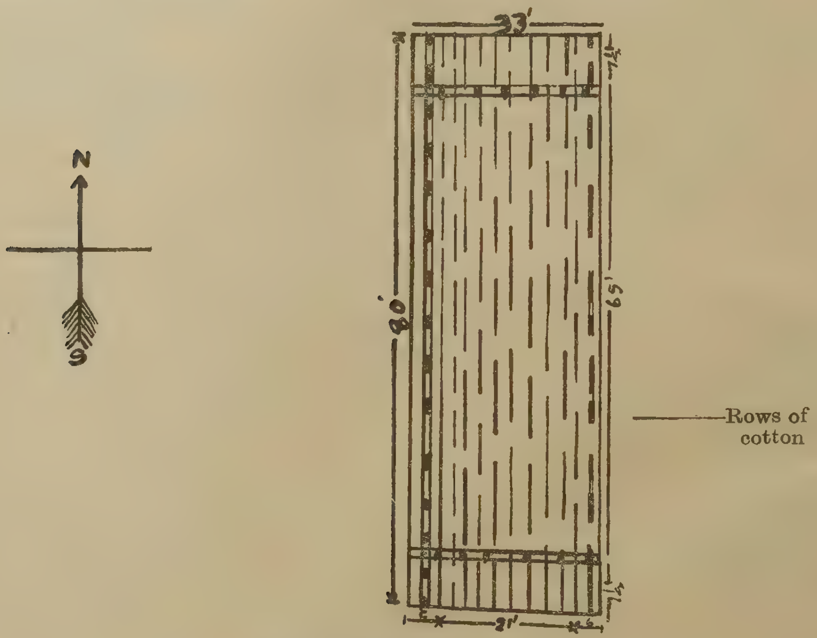


FIG. 1. Areas for harvest

In order to facilitate picking one half of each plant in the row shown above as was cut down. The total border area therefore consisted of two strips of 7½ ft. × 33 ft. = 495 sq. ft. and a strip of three rows (3 ft. spacing between rows and 1½ ft. on the eastern and western sides) = 11 ft. × 65 ft. = 715 sq. ft.

Therefore total border area = 1210 sq. ft. = 1/40th of an acre nearly.*

The area of central portion was = 21 ft. × 65 ft. = 1365 sq. ft. = 1·25 *gunthas* = 1/32 of an acre.

3. *Soil.*—Alluvial, loam.
4. *Variety.*—285F_2.
5. *Date of sowing.*—1st to 3rd May, 1935.

---

* As it was not possible to determine how far inwards the border effect penetrated on the northern and southern sides, the central portion of 1·25 *gunthas* was picked separately. Nor was any attempt made to investigate into the extent of border effect by picking border rows in different strips or rows.

6. *Spacing.*—3 ft. between rows.

7. *Treatments.*—The number of treatments given was six.

The letters A, B, C, D etc., are used to denote the six treatments, which are given below.

The following is the order of treatments in so far as the quantities of manure are concerned.

A. Control (no manure).
B. 15 cart loads compost before sowing
C. 7½ ,, ,, ,, +20 lbs. nitrogen after 3½ months.
D. 7½ ,, ,, ,, +40 lbs. nitrogen after 3½ months.
E. 7½ ,, ,, ,, { +10 lbs. nitrogen after 1½ months.
{ +10 lbs. nitrogen after 3½ months.
F. 7½ ,, ,, ,, { +20 lbs. nitrogen after 1½ months.
{ +20 lbs. nitrogen after 3½ months.

(Nitrogen added in the form of sulphate of ammonia.)

Thus the plots with treatments D and F received the maximum dose of manure. A reference to this will be made later.

8. *Dates of pickings.*— I. 8th October, 1935.
II. 27th November, 1935.
III. 8th January, 1936.

Results

The following is the plan of the experiment and the yield obtained (lbs.) :—

IV

I	A 35 (65) +4·3	D 43 (84) +9·3	C 43 (77) +0·0	F 53 (96) +0·9	E 42 (74) —2·4	B 37 (71) +8·1	A 30 (58) +8·3	D 43 (82) +7·0
II	B 56 (109) +8·9	E 45 (99) +28·4	D 68 (110) —11·0	A 32 (66) +17·2	F 49 (88) +0·0	C 47 (79) —7·5	B 46 (67) +4·2	E 43 (88) +15·1
III	C 51 (91) —1·0	F 54 (90) —8·3	E 50 (93) +4·0	B 37 (75) +14·9	A 34 (59) —4·4	D 48 (85) —2·1	C 41 (77) +4·9	F 52 (98) +5·8
					C 54 (92) —5·6	F 43 (91) +19·8	E 52 (91) —2·9	B 42 (77) +2·4
					B 41 (92) +28·0	E 39 (81) +17·9	D 50 (95) +6·0	A 27 (64) +35·2
					D 69 (126) +1·5	A 30 (70) +33·3	F 43 (83) +8·1	C 38 (86) +28·9

V VI

Note.—Nitrogen content of sulphate of ammonia is about 20 per cent.
∴ 10 lbs. nitrogen = 50 lbs. of sulphate of ammonia.
∴ 20 lbs. nitrogen = 100 lbs. of sulphate of ammonia.
∴ 40 lbs. nitrogen = 200 lbs. of sulphate of ammonia.

In the above plan, blocks are bounded by double lines and plots by single lines. The letters denote the treatments. The figures outside the brackets show the yield from the central portion while those inside the brackets the total yield of the central portion and the surrounding borders. The third figure denotes the percentage increase in yield per unit area when the border-yield is added to that of the central portion.

STATISTICAL ANALYSIS

The above yields were analysed in three ways :—

(*i*) Yields of central portions only; borders discarded.

(*ii*) Yields of central portions and their surrounding borders together.

(*iii*) Percentage increases per unit area when yields of border rows are added to those of the central ones.

Tables I and II show the analysis of variance, the mean yields of seed cotton per acre, mean per cent increases and the significance of difference with and without border effects.

TABLE I

Analysis of variance of plot yields

Due to	Degrees of freedom	Without border		With border		Per cent increase	
		Mean squares	*P*	Mean squares	*P*	Mean squares	*P*
Blocks . . .	5	58·58		55·02		256·76	
Treatments . .	5	339·52	$<0·01$	779·5	$<0·01$	149·73	$>0·05$
Error . . .	25	43·85		136·55		171·14	

TABLE II

Summary of results

		Mean yield in lbs.						General mean	Standard error of treatment mean	Whether the general effect of treatments is significant by z test	Critical difference for significance in lbs. per acre	Significance of differences
		A	B	C	D	E	F					
Without border	Per acre	1003	1328	1413	1712	1440	1568	1411	86·5			
	Percentage on general mean	71·1	94·1	100·1	121·3	102·1	111·1	100	6·14	Significant on 5 per cent	252 on 5 per cent	D F E C B A
	Per cent on control	100	132·4	140·9	170·7	143·6	156·3	...	...			
With border	Per acre	1137	1468	1498	1729	1575	1622	1505	84·7			
	Percentage on general mean	75·5	97·6	99·5	114·9	105·7	107·7	100	5·7	Significant on 5 per cent	247 on 5 per cent	D F E C B A
	Per cent on control	100	129·2	131·7	152·1	138·6	142·8	...	...			
Per cent increases	Per acre	15·7	11·1	3·3	1·8	10·0	4·4	7·7	4·6			
	Percentage on general mean	203·2	144·0	42·7	23·2	130·1	56·9	100	59·1	Not significant on 5 per cent		
	Per cent on control	100	70·8	21·0	11·4	64·0	28·0					

Under 'significance of differences', treatments not differing significantly in yields are bracketed together.

It may be noted that 'the mean per cent increases' are not proportional to the differences between their acre-yields with and without borders, since the weightage in the two cases is different.

DISCUSSION

The mean per cent increase is highest in A, *i.e.*, control and goes on diminishing with increasing quantity of manure (Table II).

The figures are noted below :—

A—15·7 (Control)

B—11·1

C & E—6·6 (mean of 3·3 and 10·0)

D & F—3·1 (mean of 1·8 and 4·0)

It therefore appears that as the quantity of manure is increased, the border rows give proportionately less yield.

There is a slight reduction in the standard error of the experiment. This may be attributed to the reduction in the variability associated with increased plot-size.

The relatively large increases in yields of plots (with borders), with decreased quantity of manure, has reduced the standard error, but this has not resulted in improving the significances. On the other hand, the significance of treatment D over treatments E and C is lost.

The tendency of decrease in differences in plot yields due to inclusion of yield of border rows may either be due to the passing on of manure directly to contiguous beds or to the intermingling of the root-systems. Though the magnitude of the error variance has been reduced by the inclusion of border rows, yet it has definitely disturbed the mean values to the extent that even the significance of treatment D over treatments E and C has been lost. Results of the work during 1936-37 have confirmed the superiority of the above treatment. It is therefore concluded that border effect need best be eliminated.

CONCLUSION

Inclusion of border rows in manurial experiments (reported in this paper) has changed the results obtained without the border, though it has resulted in some reduction in the standard error.

SUMMARY

With a view to study the effect of inclusion or rejection of border yields from the total yield of a plot, the yields from border rows and central portions of plots under manurial experiments on cotton were separately picked and weighed.

The data was subjected to statistical analysis and it was found that, with the inclusion of border yields,

(*i*) the percentage increase in the total yield was highest in control plots, while it regularly diminished with increasing quantities of manure in treated plots,

(*ii*) the standard error of the experiment was reduced, but it did not improve significances,

(*iii*) there was a disturbance in the mean values of the treatments, so that the significance of the best treatments was lost. Marginal effects should, therefore, be eliminated while conducting manurial experiments on cotton.

ACKNOWLEDGMENTS

Our thanks are due to Rao Bahadur M. Vaidyanathan, Statistician to the Imperial Council of Agricultural Research, New Delhi, and Mr. J. B. Hutchinson, late Geneticist, Institute of Plant Industry, Indore, for their criticism of the data and suggestions about the interpretation of results.

REFERENCES

Christidis, B. G. (1935). *J. Agric. Sci.* **25**, 231

Coombs, A. V. (1934). *Emp. J. Expt. Agric.* **2**, 315

Deming, G. W. and Brewbaker, H. E. (1934). *J. Amer. Soc. Agron.* **26**, 615

Hollowell, E. A. and Heusinkveld, D. (1933). *J. Amer. Soc. Agron.* **25**, 779

Hutchinson, J. B. and Panse, V. G. (1935). *Ind. J. Agric. Sci.* **5**, 671

Immer, F. R. (1932). *J. Agric. Res.* **44**, 649

Justesen, S. H. (1932). *J. Agric. Sci.* **22**, 366

Kalamkar, R. J. (1932). *J. Agric. Sci.* **22**, 373

McClelland, C. K. (1929). *J. Amer. Soc. Agron.* **21**, 524

——————— (1934). *J. Amer. Soc. Agron.* **26**, 491

SOILS OF THE DECCAN CANALS, I

GENETIC SOIL SURVEY AND SOIL CLASSIFICATION: NIRA RIGHT BANK AND PRAVARA CANALS

BY

J. K. BASU, M.Sc. (CAL.), PH.D. (LOND.)

Soil Physicist, Sugarcane Research Scheme for Deccan, Padegaon*

AND

S. S. SIRUR, B.AG. (BOM.)

Senior Assistant

(Received for publication on 8th March 1938)

(With Plates LIV-LVI and eight text-figures)

CONTENTS

PAGE

I. GENERAL— 637

Introduction—Geography—Climate and vegetation—Geology—Soils and irrigation

II. METHODS OF EXAMINATION— 645

Field and laboratory methods

III. PRESENTATION OF DATA AND DISCUSSION— 650

Soils types A to H—General information—Morphological descriptions—Mechanical and physico-chemical soil characteristics

IV. GENERAL DISCUSSION 686

V. POSITION OF THE SOILS IN THE WORLD GROUP OF SOIL CLASSIFICATION. 689

VI. A SCHEME OF SOIL CLASSIFICATION FOR THE DECCAN SOILS . . 694

VII. SUMMARY AND CONCLUSIONS 695

REFERENCES 696

GLOSSARY 697

I. GENERAL

Introduction

The present paper deals with the survey and classification of the soils occurring in the canal zones of the Bombay-Deccan. This work forms an integral part of the soil investigations that are being carried out at the Bombay-Deccan Sugarcane Research Scheme, Padegaon, with regard to the vital question of soil deterioration under perennial irrigation which has been responsible for a considerable falling off in sugarcane yields in certain parts of the irrigated tract. For a systematic study of these problems it was considered that a classification of the soils into specific types and a thorough understanding of their nature was an essential pre-requisite for the maintenance of soil fertility over a long period by proper adjustment of water, manure and crop rotations.

---

*This scheme is partly subsidised by the Imperial Council of Agricultural Research.

Before 1932, our knowledge of the soils of this tract was very meagre. There were very few surveys as such and, in some cases, the not inconsiderable analytical data, in common with the general practice so far in India, were obtained to ascertain the agricultural value of the soil rather than its fundamental characteristics. To this category belongs most of the information compiled in "Soils of the Bombay Presidency" by Sahasrabuddhe [1929]. Two systems of soil classification, however, are in vogue, one followed by the Revenue Department [Mollison, 1900] for assessing the productivity of land, and the other devised by the Irrigation Department [Inglis and Gokhale, 1929] for determining the suitability of lands for irrigational purposes. The former, based mainly on the depth and the texture of the soil as determined by very simple field tests and certain other characteristics gives a fair index of the productivity of the soil under rain-fed conditions. The second, also based on depth, is supplemented by certain laboratory determinations, chiefly of a physical nature. As none of the methods are suitable for ascertaining the agricultural behaviour of soils under irrigation, the modern method of soil survey was adopted, which satisfies the conditions of such a study.

Geography

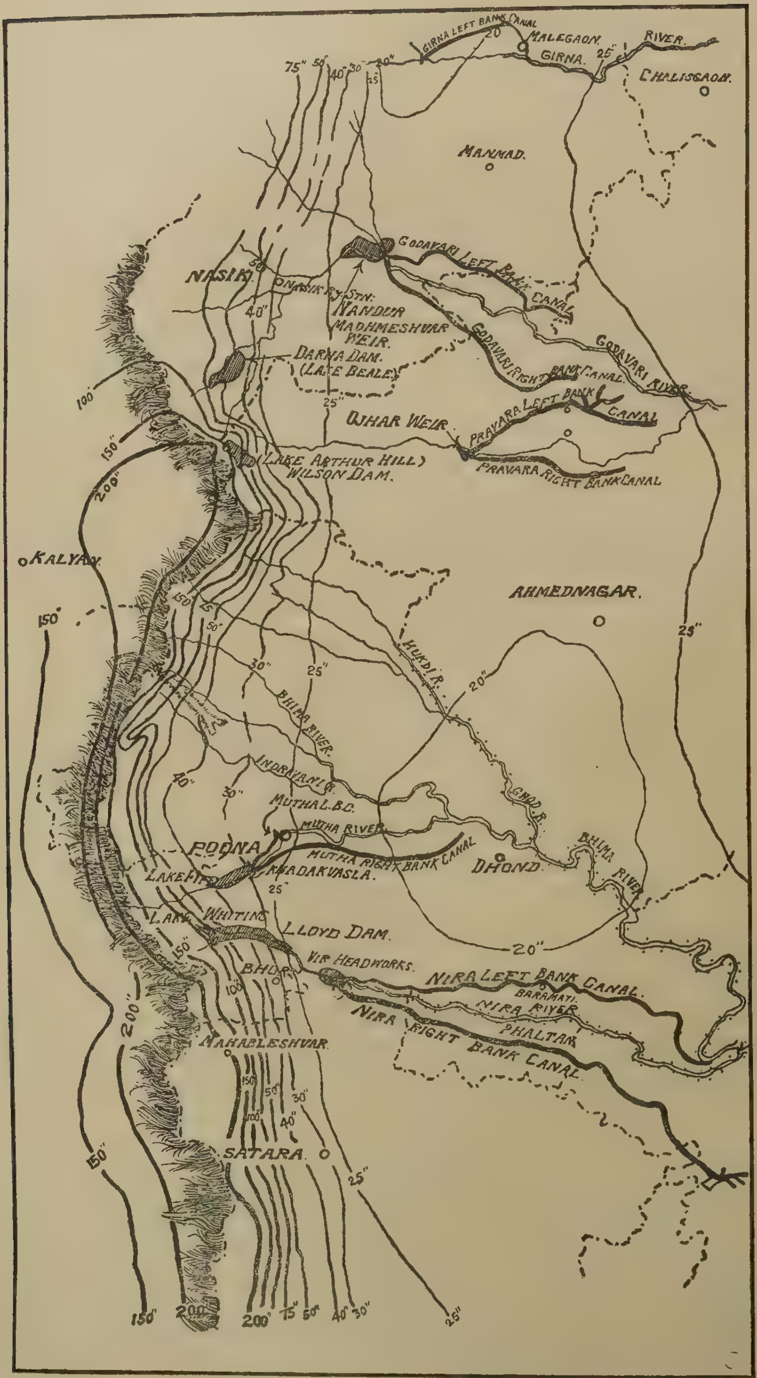
The Deccan canals cover, with a network of water channels and distributaries, more than a million acres of land lying between the parallels of latitude 16° and 21° N.L. of the great plateau of Peninsular India. For a proper appreciation of the geographical situation of these soils reference may be made to the divisions of natural regions made by Schokalsky [1933]. It has been pointed out therein that " Peninsular India displays more or less meridionally situated zones ; roughly speaking three, greatly differing in width, may be distinguished: the narrow western coast, the whole of the inner portion of the peninsula and the eastern coast with its river valleys penetrating far inland."

However, because of the fact that this part of India extends over a very considerable area, *viz.*, from 8° N.L. to 24° N.L., Schokalsky has further divided each of these meridional zones into two latitudinal zones, six regions being thus obtained. Again she has excluded two tracts for separate treatment, due to their distinct climatic differences with the rest of the Peninsula, *viz.*, the north western regions consisting of the peninsula of Kathiawar and Cutch and the adjacent alluvial flat of the Gujerat Districts, and secondly the mountain ranges of the Vindhyas and Satpuras. The six divisions of the main body of the Peninsula after excluding the above two may be termed respectively: (1) the North Western, (2) the North Central (3) the North Eastern and similarly (4) the South Western, (5) the South Central and (6) the South Eastern.

The North Central region thus enumerated above forms a strip of 5°-6° of latitude in length from north to south. The slope of the country is from west to east, all the rivers flowing in an easterly direction. There is great variation in the rainfall which is very heavy on the Western Ghats, which form the western boundary of the region, and in their vicinity, and rapidly decreases on the plains towards the east. " So great is the difference in the climatic conditions of the submontane region and of the plateau in the proper sense of the term, that three distinct regions with a main meridional trend may be distinguished ; these are : the Dangs—a rough hilly country, 15-60 kms. broad, which has a rich drainage system ; the transition tract, extending just beyond the first along the foot hills, and finally, the Desh country, with mean annual precipitation of 450-700 mm. ; this is the central driest region, as approaching east there is again an increase of moisture " [Schokalsky, 1933]. It is in this central driest region—the Desh tract—comprising smaller or larger parts of the districts of Ahmednagar, Poona, Satara and Sholapur, that the area, whose soils are under investigation, mainly lies. The mean elevation of the tract above sea-level varies from 1800-2200 ft.

Climate and vegetation

The great aridity of the Bombay-Deccan marks it out as a distinct climatic zone with an average annual precipitation of less than 25 in. (Fig. 1) which is ill-distributed and precarious. The climate is sub-tropical and more or less of a continental type possessing well-defined rainy and dry seasons.


GIRNA LEFT BANK CANAL
MALEGAON
GIRNA
RIVER
CHALISGAON
MANMAD
GODAVARI LEFT BANK CANAL
NASIK
NASIK RY. STN.
NANDUR
MADHMESHWAR WEIR
DARNA DAM.
(LAKE BEALE)
GODAVARI RIGHT BANK CANAL
GODAVARI RIVER
OJHAR WEIR
PRAVARA LEFT BANK CANAL
PRAVARA RIGHT BANK CANAL
(LAKE ARTHUR HILL)
WILSON DAM.
KALYAN
AHMEDNAGAR
HUKDI R.
BHIMA RIVER
INDRAYANI R.
MUTHA L.B.C.
MUTHA RIVER
POONA
MUTHA RIGHT BANK CANAL
KHADAKVASLA
LAKE FIFE
GHOD R.
DHOND
BHIMA RIVER
LAKE WHITING
LLOYD DAM
BHOR
VIR HEADWORKS
NIRA LEFT BANK CANAL
BARAMATI
NIRA RIVER
PHALTAN
NIRA RIGHT BANK CANAL
MAHABLESHWAR
SATARA
75"
50"
40"
30"
20"
25"
100
150"
200"
150
50"
30"
25"
40"
30"
20"
25"
20"
150"
100
200"
150
50"
30"
100
40"
25"
150'
200
200'
75"
50"
40"
30"
25"

[Scale 34 miles = 1"

FIG. 1. Major canal systems and rainfall in the Bombay-Deccan (Adapted from map in *Bom. P. W. D. Tech. Paper No.* 49)

The rainy season is of short duration and usually commences by the middle of June and ends by middle of October with occasional heavy showers in November. The early showers (from June to August) are gentle and wet the soil uniformly only to a limited depth which gives the natural vegetation a great fillip for vigorous growth. The later rains are torrential and usually come in heavy downpours. It is this later precipitation which is really responsible for carrying down most of the products of soil-weathering (including clay) into the lower soil layers or into the *murum* below when the soils are shallow and also for considerable soil erosion in sharper gradients on the hill slopes. This effective rainfall, however, greatly varies from place to place due to the varied topography, and a low-lying soil possessing a good catchment area may occasionally be subjected to a considerable amount of leaching.* Again due to lower humidity of the air the rate of evaporation of moisture is very high and the total evaporation from a free water surface† may run up to over a hundred inches during the course of a year. Hence the rainfall is usually heavily outweighed by evaporation in this tract, especially when the precipitation is gentle. The evaporation rate increases steadily from February to May and it is during this period that the desiccation of the soil progresses most rapidly. Most of the weeds which seek moisture at lower layers after the cessation of monsoon now start wilting, thus adding a large amount of organic matter on the surface as well as to the lower depths. The natural vegetation is, therefore, of a sparse type akin to that of the dry steppes consisting mostly of annual grasses and shrubs. The decomposition of this organic matter goes on rapidly with the production of large quantities of carbonic acid until the soil dries up so completely as to prevent most of the biological and chemical processes until the first showers of rain bring life into the soil again. The duration of this inactive period depends on the soil depth as well as on the situation of the land (subsoil water may some time play an important role in altering the soil conditions).

The atmospheric temperature rises steadily from March to May, the maximum temperature (110°F. or so) being attained sometime in April, after which with the first showers of rain, there is always a sudden and great drop in temperature which remains fairly constant until October. The months of November to February are cooler and the coldest spell is experienced in January with a minimum of about 45°F. Frosts occur only occasionally. They are not usually widespread and their duration is limited to one or two days at the most. The frost of 1929 affected an extensive area and continued for about a week. The effect of frost on soil conditions has not been studied in detail. Observations on soil temperature taken at Surat [Joshi, 1930] during the same frost showed that " in contrast to the air temperatures, the soil temperatures were very high and were not low enough to kill the root-systems of the crops." While the minimum air temperature dropped from

---

*We recall with gratitude discussions on various occasions with Rao Saheb B. P. Vagholkar, Principal Agricultural Officer, Sugarcane Research Scheme for Deccan, Padegaon, about the influences of topography on the effective rainfall, in which his original suggestions have been of considerable help in the clarification of the subject.

†This is calculated from the figures obtained from an open-pan evaporimeter.

62°F. to 40°F. the minimum temperatures of the first 3 in. of soil showed a drop from 72°F. to 65·5°F. during the cold week. Excepting during the monsoon the fluctuations in the daily atmospheric temperatures are great (30° to 40°) and may be considered as a potent factor in soil-weathering. The atmospheric temperature however does not indicate the nature of thermal changes that may take place in soils possessing different depths. An illustration is given below to indicate the extent of variation in soil temperatures that may occur in some typical soils.

TABLE I

Average weekly soil temperatures (0-4 in.) in light and heavy soils on the Padegaon Farm (°F.)

Week ending	Light soil (1½-2 ft. deep)		Heavy soil (8-10 ft. deep)	
	8 A.M.	3 P.M.	8 A.M.	3 P.M.
29th January 1937	62·8	83·3	60·6	74·2
5th February 1937	67·2	83·2	65·6	76·9
12th February 1937	69·0	89·4	67·5	78·4
19th February 1937	64·9	87·6	64·4	80·3
26th February 1937	67·4	85·9	65·7	82·9
5th March 1937	68·1	85·1	67·0	81·4
12th March 1937	69·6	85·3	67·3	82·6
19th March 1937	72·4	88·9	69·3	83·0

It clearly shows that a shallow soil is subjected to greater fluctuations in temperature as well as to a higher absolute temperature than a soil of greater depth. Pedogenic processes are thus likely to be of greater intensity in the former but of shorter duration due to the limiting factor of moisture. Some typical meteorological data of the Padegaon Farm (which fairly represents the climate of the canal tract) are given in Table II.

TABLE II

Average monthly weather record at Padegaon

Month	Temperature (°F.)		Humidity per cent		Evaporation	Rainfall	No. of rainy days
	Maximum	Minimum	8 A.M.	3 P.M.			
	Average of 4 years		Average of 3 years			Average of 15 years	
					In. C.	In. C.	
January	85·60	51·24	73·79	31·70	0—21·5	0—04	0·20
February	90·93	52·74	65·52	21·20	0—31·4	0—02	0·07
March	96·89	59·87	50·38	15·90	0—41·5	0—27	0·73
April	101·14	68·11	51·52	15·30	0—55·2	0—53	2·00
May	100·89	72·25	56·37	19·10	0—58·6	0—75	2·00
June	89·76	72·08	74·53	49·10	0—34·4	2—90	7·73
July	85·93	71·20	80·85	63·70	0—24·8	1—77	10·73
August	83·53	70·10	83·06	64·10	0—23·1	2—12	7·13
September	85·90	68·60	83·53	53·60	0—25·6	5—04	9·60
October	88·95	66·19	78·07	45·00	0—26·0	2—89	7·00
November	84·68	56·80	79·91	41·60	0—18·8	2—25	2·87
December	84·09	51·75	77·19	34·00	0—17·7	0—22	0·73

Mean annual temperature	76·63°F.
Mean annual humidity	54·56 per cent
Total annual rainfall	18·80 in.

The agriculture of the land is of a simple nature due to the uncertain nature of the rainy season. When the early rains are good usually *bajri* (*Pennisetum typhoideum*) is taken whereas with successful late rains *rabi jowar* (*Andropogon Sorghum*), gram or wheat are grown extensively. These dry cultivations with occasional fallows have been practised over such a long period in this tract before the introduction of irrigation that they may be considered as part and parcel of the soil-forming processes in the Deccan. Human interference is thus reflected in the profile development of most of the culturable soils.

Geology

The soils under the present study invariably lie upon, and owe their origin to the Deccan trap. This is an extensive volcanic formation of basaltic rocks which has been studied in numerous investigations by the Geological Survey of India and has been fully dealt with by Wadia [1926] in his book on Indian Geology. The Deccan trap at the present day extends over an area of nearly 200,000 sq. miles, and includes, besides Bombay-Deccan, large tracts of the northern part of the Indian peninsula like Cutch, Kathiawar, Central Provinces, etc. The term ' trap ' is applied to different kinds of rock but in this case it is used " as a Swedish word meaning ' stairs ' or ' steps ', in allusion to usual step-like aspect of the weathered hills of basalts which are so common a feature in the scenery of the Deccan."

To deal with certain salient characteristics of this rock formation from the view-point of the soils resulting from it, it is interesting to note, fro the same authority that " in petrological composition, the Deccan basal are singularly uniform. The most common rock is a normal augite-basa of mean specific gravity 2·82. This rock persists, quite undifferentiated in composition, from one extremity of the trap area to the other." However, there is unfortunately rather meagre information regarding the chemical analysis of the rock, and as to how this is likely to be correlated with the petrological composition. It appears feasible that, apart from bases like calcium, magnesium and iron which are in virtual abundance, even small differences in the composition of the rock from place to place may result in pronounced differences in the usually less abundant constituents, like phosphoric acid and potash, important from the point of view of plant growth and also in the formation of a constituent like free lime in the soil which plays an important role in the fertility of soil. Other properties of the underlying rock which have an important bearing on the pedogenic processes in the soil are the comparative hardness of the rock, and the general habit and direction of its cleavage, all of which partly determine the ease with which water is allowed to leach through the mass of soil.*

---

*The personal observations of Rao Saheb B. P. Vagholkar regarding the variation in drainage and hardness of the rock and the *murum* and its consequent effect on the overlying soil have stimulated our ideas on this aspect of soil formation.

The most common colour of the rock is greyish-green with lighter or deeper shades. " A few, especially those of trachytic or more acid composition are even of a rich brown or buff colour ; less common are red and purple tints."

So far as common soil-forming minerals are concerned it may be mentioned that " the bulk of the rock is composed of a fine-grained mixture or ground-mass of felspar and augite." Regarding the influence of the composition of the rock on the sodium and potassium contents of soils respectively, it is interesting to note that " besides abundant plagioclase (labradorite or anorthite) prisms, there occur sometimes large tabular crystals of clear glassy orthoclase (sanidine or adularia) as pheno-crysts in the ground-mass. Magnetite is abundantly disseminated through the ground-mass. Primary accessory minerals, like apatite, are few but secondary minerals are many, *viz.*, calcite, quartz, chalcedony, ... Glauconite is abundant as a coating round the kernels."

In making a passing reference to the age of the Deccan traps it may be mentioned that they have been placed in the Cretaceous period from external evidence, the traps themselves being mostly unfossiliferous and do not provide conclusive evidence of their age.

Soils and irrigation

In spite of this seeming uniformity of conditions in this part of the Deccan plateau, many diverse soil types exist side by side. The causes for this phenomenon have to be sought not so much in differences in the nature of the parent material or in the climate, but in the varied topography and the drainage conditions of the soils which have so largely modified the soil climate. Although the soil-building forces are still at work, due to the dynamic nature of the relief, yet these soils must have reached a state of equilibrium with climate, natural vegetation and long-standing agricultural practices. The introduction of irrigation with its set of different croppings has set up an entirely new growth and development of these soils. For a proper estimation of such far-reaching effects it was necessary, therefore, to adopt a system of soil classification which would not only take into consideration a certain depth of soil arbitrarily fixed, but the soil as a whole which has been considered as "an independent, natural, historical body" according to the modern conception of soil science. For the present investigation, the genetic system of soil classification, as first developed in Russia and now adopted by various countries of the world, was followed. This system has, for its main principle, that the entire soil-forming processes find an expression in the ' soil profile ' or the vertical section of the soil.

II. METHODS OF EXAMINATION

Since the final object of a survey is to map out areas of similar soils, its success naturally devolves on the selection of a site which would thoroughly represent the given area in each case. The modern method, as worked out in the United States and found to be very useful there [Russell, 1932], consists of the detailed study of standard profiles and the subsequent grouping of soils having similar profiles. A similar general plan was, therefore, adopted for the present survey, whereby a large number of profiles from representative fields were subjected to a preliminary examination, followed by a detailed study of typical ones among them.

Selection of site

The main programme of the survey was to examine in detail good arable soils suitable for sugarcane commanded by each canal. Such soils, however, are not uniformly distributed, being concentrated at irregular intervals along the canals and having varying extents on the different distributaries. In certain places their extension is very limited, being interspersed with considerable areas of inferior land, *e.g.*, either of alkali soil or of very shallow soil. The latter types of soil as also certain soils of an alluvial nature have been left out of consideration for the present. Under such circumstances an exact grid system could not be followed. But in order to cover as wide an area as possible and also to get a thorough idea of the type variation, spots were examined at as frequent intervals as possible, even in places where normal soils were only limited in extent. It can be said, on an average, that soils were examined in greater or lesser detail at every third or fourth mile along the canal.

Representative fields were selected according to the colour and general characteristics of the soil at the surface as determined by visual examination. It is important for this kind of survey that the soil to be examined should be in its natural condition undisturbed by drastic changes due to any kind of natural or artificial interference. Therefore, while virgin land would be the ideal for study, it is rarely, if at all, available, most of the land having been under dry cultivation for very long periods under the Deccan conditions. In fact as it has been pointed out elsewhere in this paper, dry farming conditions may be considered to be a necessary item in the soil-forming processes. Thus in all cases this was made the basis of study for soil examination and sites were always selected in fields under dry cultivation, carefully avoiding, however, those in which there had been intense and long-continued agricultural operations, manuring or irrigation.

Technique of profile examination

In view of certain peculiarities of the conditions prevailing here the technique of profile study had to be modified wherever necessary.

Rectangular pits were dug for exposing the soil profile to a depth a few inches below the *murum* which usually underlies the soil. The side of the pit to be examined is made exactly vertical and planed down by a sharp spade to give a smooth surface taking care that no rubbing occurred which would disturb the structure or concretions therein. The pit is required to be made so as to receive full sun-light on this surface, such illumination being necessary for these dark-coloured soils and found to be the most convenient for the study as well as photography of the profile. For this purpose the marking of the pit is made in the same direction as that of the shadow of a stick or rod if the subsequent examination is to be made in the corresponding time of the day. Otherwise a compass needle is necessary to fix the direction of the pit.

The size of the pit depends on the depth of soil. For a soil having a depth of 2 ft. pits of 3 ft. × 3 ft. were found to be convenient, this amount of space being just necessary for standing in the pit and for profile examination. As the depth of soil increases, the length of the pit has to be increased likewise to allow full sunlight on the profile face of the pit. For this purpose it is sufficient to cut the side opposite the profile face so as to make an inclined plane. This not only saves labour of digging, but is also convenient for descending into the pit for which rough steps may be made. Convenient dimentions of pits for soils having depths of 4, 5 and 6 ft. respectively would be 6, 8 and 12 ft. with a width of 3½ ft. in each case.

After ascertaining the depth of the soil by means of a screw auger several pits are usually dug in a field. The profiles are all generally examined at first to make sure that they are all similar and that there is no vitiation. The most mature profile is taken for detailed study, while the shallower and immature ones provide for a study of phase differences.

As dry soil is desirable for describing a profile, usually a couple of months must be allowed to elapse after the rains before the survey work can be undertaken. In each place, general information regarding locality, vegetation, relief, drainage and sub-soil water table, etc., is collected and entered in a ' profile form '.

In the study of the profile, horizons are first determined by colour differences, if any, and the thickness of each of these measured. These are further sub-divided according to the structure, texture and concretions, and samples taken from each of these sub-horizons. In case the whole profile is uniform in colour and structure, six-inch samples are collected. The following field tests are usually carried out :—

(*i*) Effervescence with dilute hydrochloric acid for carbonates, (*ii*) soil reaction with a ' universal indicator ' as provided by the B.D.H. or similar soil testing outfits, (*iii*) structure and compaction by means of a penknife, (*iv*) texture by the ' feel ' of a wet mass of soil after kneading it with water, (*v*) occasional tests for chlorides, sulphates or sodium carbonate, (*vi*) counting of concretions per unit area by means of square apertures, (*vii*) diagrammatic colour sketch of profile by means of crayons, (*viii*) photos of profiles wherever necessary.

Collection of monoliths

Monoliths being natural records of profiles that are examined, those of the principal soil types have been collected and preserved. The taking of monoliths presented many difficulties at first, due to the very heavy nature of the soils and a suitable procedure had to be worked out. The method of taking a monolith is to collect a column of soil *in situ* 9 in. in breadth, of length corresponding to the depth of the profile, and of 2 in. thickness in a strong wooden box. The back of the box and its front door (provided with a glass pane) are fixed by means of screws which can be easily taken out.

For collection of monoliths the same vertical side of the pit made for profile examination may be used, after cutting it afresh if necessary. On the smooth vertical side the frame of the box (after removal of the back and the door) is applied with the top of the box at the same level as that of the soil surface, and an outline of inner area of the box marked out. The soil is carefully cut away for some distance all round on the outside of this line with sharp knife to make a column of soil of a thickness of 3-4 in. stand out in relief. The frame of the box is carefully fitted on to this protruding soil column so that it is just enclosed within.

At this stage a temporary wooden door is fixed to the box. In light soils it would be possible to detach the enclosed soil column by merely cutting or sawing it off from the main body of soil. But in heavy soils such a procedure is not possible. It was found to be necessary under these conditions to have, previously, a second similar pit behind and in line with the first, but at a little distance from it, so that a wall of soil about a foot in thickness separates the two pits. The monolith is cut out from this wall as described. After fitting the box frame on to the protruding monolith, the soil is cut away carefully on all sides so as to detach a pillar-like soil column. This pillar, with the box still fitted on to the monolith, is then firmly tied all over by a thick rope to keep the soil intact and gently hauled to one side to detach it from the bottom (Plate LIV). It is then carried above the pit and carefully cut and finally scraped flush with the box, and the back of the box screwed on. After removal to the museum the wooden door is replaced with the proper door with a glass pane.

Laboratory examination

The soil samples, after being brought to the laboratory, are air-dried, ground to pass through a 2 mm. sieve and stored in galvanised iron tins.

For preliminary analysis of profile samples, rapid methods were employed and these, together with the field tests, gave sufficient material to classify the soils broadly. Determinations under this head included *p*H, total salts, calcium carbonate and humus. Finally for characterising the soil types very detailed analysis was done.

The following contains brief epitomes of the analytical methods employed.

Mechanical analysis.—By the international method : pre-treatment with hydrochloric acid and hydrogen peroxide and dispersion with *N* caustic soda.

Carbonates.—By Scheibler's Calcimeter : One grm. of soil passing 100-mesh sieve treated with 10 per cent hydrochloric acid and the liberated carbon dioxide measured by the replacement of air.

Cutting out a soil monolith

Total soluble salts.—Determined by the Leeds and Northrup Soil Conductivity Bridge. Factors worked out by the U. S. Bureau of Soils adopted [Davis, 1927].

Humus.—Sigmond's method [1927, 1]. Twenty-five grms. air-dry soil extracted with 250 c.c. of $N/10$ sodium carbonate. The dissolved humus in 25 c c. of extract oxidised with excess of $N/10$ potassium permanganate. An equal volume of $N/10$ oxalic acid run in and excess titrated with $N/10$ potassium permanganate. The c.c. of $N/10$ potassium permanganate required in the final titration represent the amount used up in oxidising the humus. Humus calculated by factor 1 c.c. $N/10$ potassium permanganate = 0·00239 grm. humus.

Hygroscopic moisture.—Ten grms. air-dry soil heated in a steam oven for six hours. Loss in weight taken as hygroscopic moisture.

Bulk chemical analysis: Extraction of the soil with concentrated hydrochloric acid.—Method of Dr. A. A. J. de Sigmond [1927, 2].— This method has been preferred to other methods as the process recommended for the estimation of silica therein is considered specially suitable for a better understanding of soil genetic processes and the method, with slight modifications, is in vogue in the principal laboratories of the European Continent. The principle of the method has been described by Russell [1932] as follows :—" On the Continent, hydrochloric acid extractions, followed by an alkaline extraction of the residue for silica rendered soluble, has been used in an attempt to distinguish weathered from unweathered material."

Ten grms. of air-dry soil passing a 2-mm. sieve are treated with 120 c.c. (100 c.c. in the case of non-calcareous soils) of concentrated hydrochloric acid of sp. gr. 1·13 in a 500 c.c. Erlenmeyer flask fitted with a vertical Liebig's condensor and maintained at a temperature of 110°C. in an oil-bath for one hour. The flask is then removed, cooled by adding about 300 c.c. of distilled water and left overnight. The acid extract is filtered through a hardened filter paper and the insoluble residue washed with hot water till free of acid, dried and weighed.

Two portions of silica are obtained. The first portion is estimated by extracting a weighed quantity of insoluble residue with caustic potash solution of sp. gr. 1·04 and evaporating the solution repeatedly with hydrochloric acid to separate the silicon dioxide. The other portion which is brought into solution by the hydrochloric acid is separated by further treatment of the acid extract by evaporating it at first three times with concentrated nitric acid to destroy organic matter and later three times with concentrated hydrochloric acid and finally completely dehydrating it on a sand bath. The silica is thrown down as a white precipitate when the dry mass is taken up with a few c.c. of hydrochloric acid and water. The acid solution is now filtered, the insoluble precipitate of silica washed free of acid, the filtrate with the washings being made up to a known volume. This final-acid extract is used for the estimation of aluminium oxide, ferric oxide, phosphoric acid, potassium oxide and other mineral constituents by standard methods.

Loss on ignition is obtained by igniting 0·5 to 1·0 grm. of the insoluble residue.

Total nitrogen.—Kjeldahl's method: Soil (10 grms.) wetted with about 50 c.c. of water previous to the addition of sulphuric acid (35 c.c.) as recommended by Bal [1925].

Soil reaction.—By the Biilman's quinhydrone method using the Veibel KCl+HCl electrode. Soil : water ratio 1 : 2·5 shaken for half a minute and reading taken immediately on an L. and N. potentiometer. Exchange acidity similarly determined after shaking with normal potassium chloride, *p*H values of 8·5 and above checked with colorimetric method. Latterly a Beckmann's *p*H-meter with glass electrode has been used.

Exchangeable bases.—The determination of the various bases in the electrodialysate is complicated due to the presence of considerable amounts of free calcium carbonate in the soil. After exhaustive trial with the apparatus devised by Basu [1931], it was found that for these soils only sodium can be successfully determined in the dialysate. The exchange sodium was found to be completely liberated within six hours. It is estimated by Zinc Uranyl Acetate Colorimetric method [Steenkamp, 1932].

For the other bases leaching with normal salt solutions had to be resorted to.

Calcium.—The method recommended by Crowther and Basu [1931] for exchangeable calcium and unsaturation as a modification of Hissink's method was followed. The figure for calcium obtained was taken as the exchange calcium, the unsaturation in these soils being considered negligible.

Magnesium.—The soil was leached with normal sodium chloride to two successive litres as recommended by Hissink. The difference between the magnesium contents of the two litres is taken as the exchange magnesium. Leaching with normal ammonium chloride considered inadvisable due to presence of magnesium carbonate in the soil. (*Imp. Bur. Soil. Sci. Tech. Comm.* No. 30, 1934, pp. 4-6).

Potash.—This was determined in the leachate of the soil with normal ammonium chloride. After charring off the ammonium salts and extraction with hot water, the potash was estimated colorimetrically by the sodium cobalti-nitrite method as described in the bulletin of the Imperial Bureau of Soil Science referred to under sodium.

III. Presentation of data and discussion

The survey of three canals, *viz.*, Nira Right Bank Canal, Pravara Left Bank Canal and Pravara Right Bank Canal has been recently completed, which comprise about 630,700 acres of culturable land. From a thorough examination of a number of profiles it has now been possible to group these soils into eight distinct types which exhibit fundamentally different soil characteristics. These eight types have been named alphabetically from 'A' to 'H' for the sake of convenience. The scope of the present paper will be to study the physico-chemical properties attendant upon the wide field differentiations of the soils which are ultimately linked up with plant growth and its response to water and manure. The general information, morphology and the results of analytical examination of each of these soils are presented here.* The soil-forming processes have been discussed for each type separately as these studies alone can give us the genetic relationship of soils.

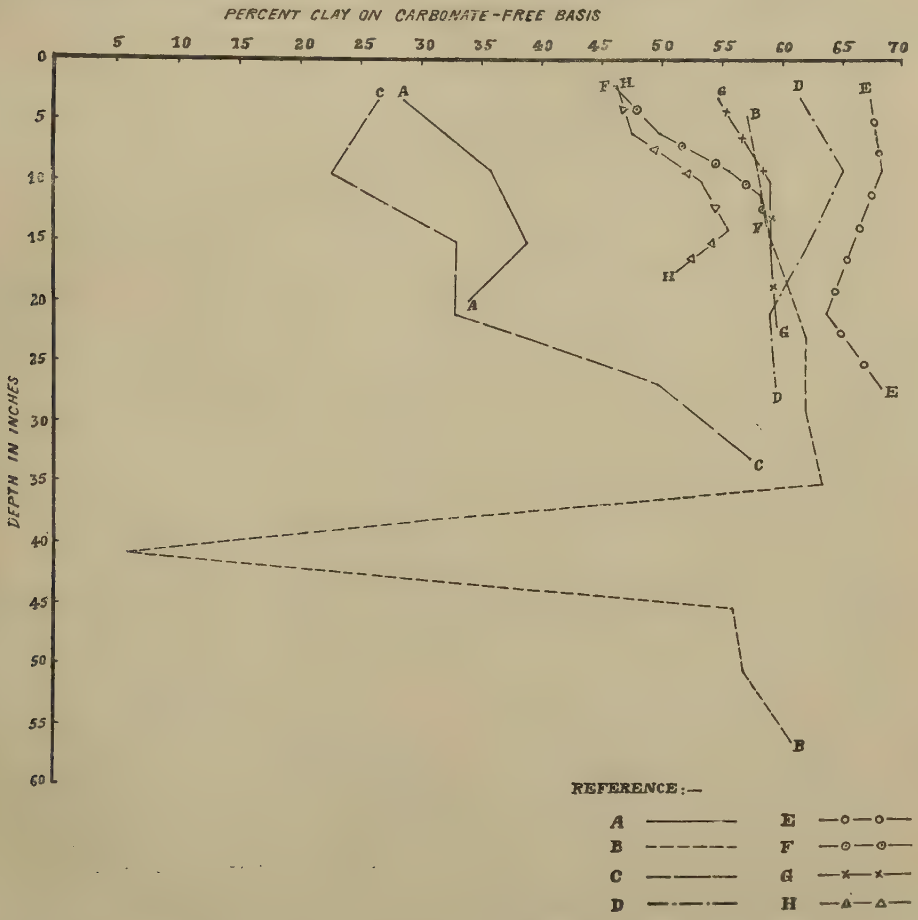


FIG. 2. Depth distribution of clay in the profiles of different soil types

---

*For discussions on clay, $CaCO_3$, humus, total salts and exchangeable bases, reference may be made to Figs. 2, 3, 4, 5 and 6-7 respectively.

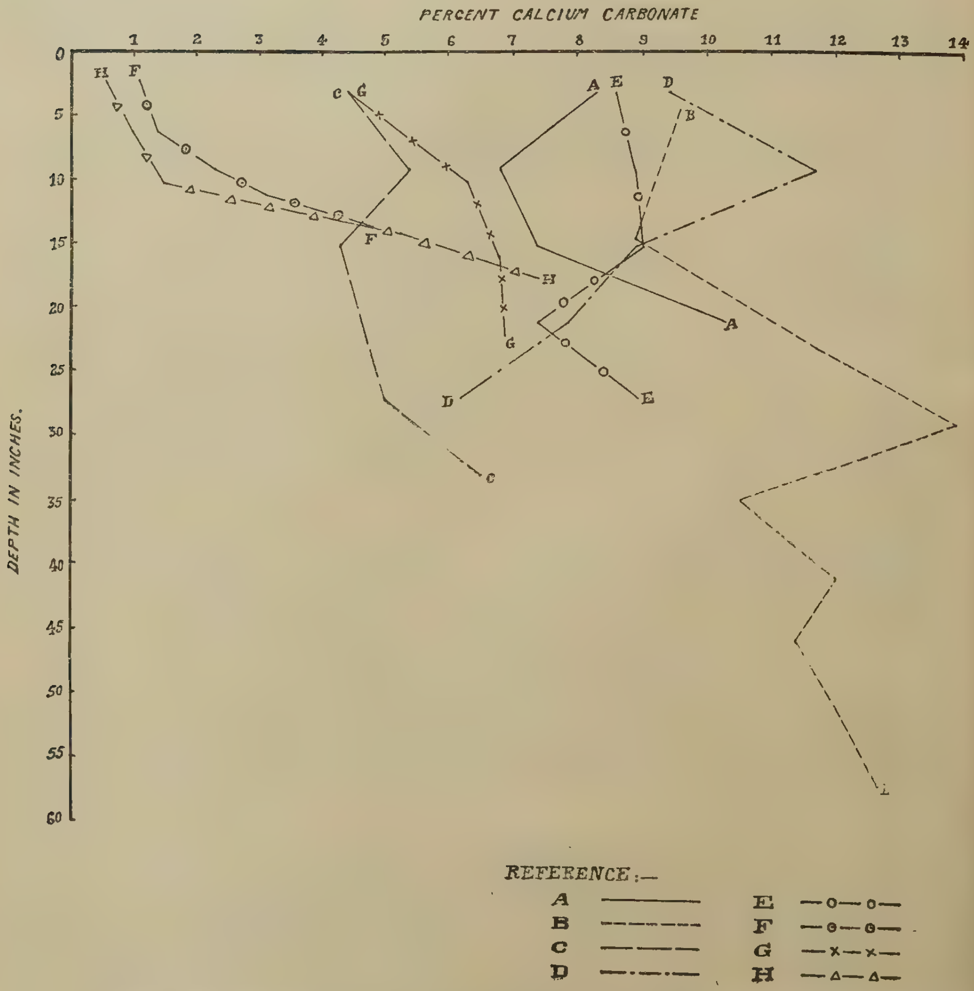


FIG. 3. Depth distribution of calcium carbonate in the profiles of different soil types

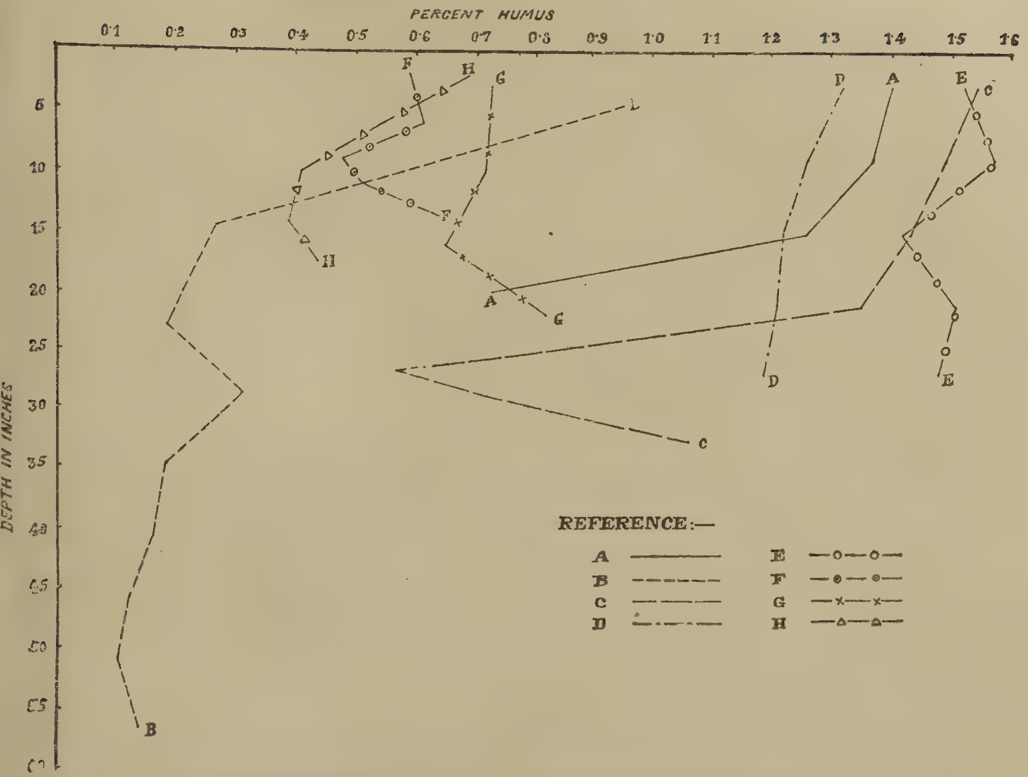


FIG. 4. Depth distribution of humus in the profiles of different soil types

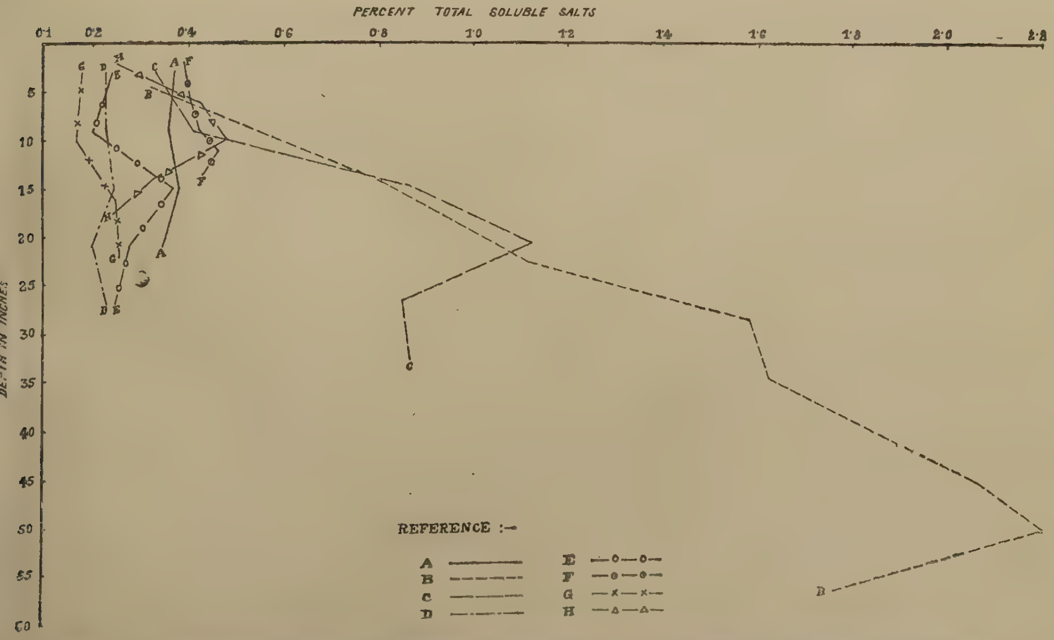


FIG. 5. Depth distribution of total soluble salts in the profiles of different soil types

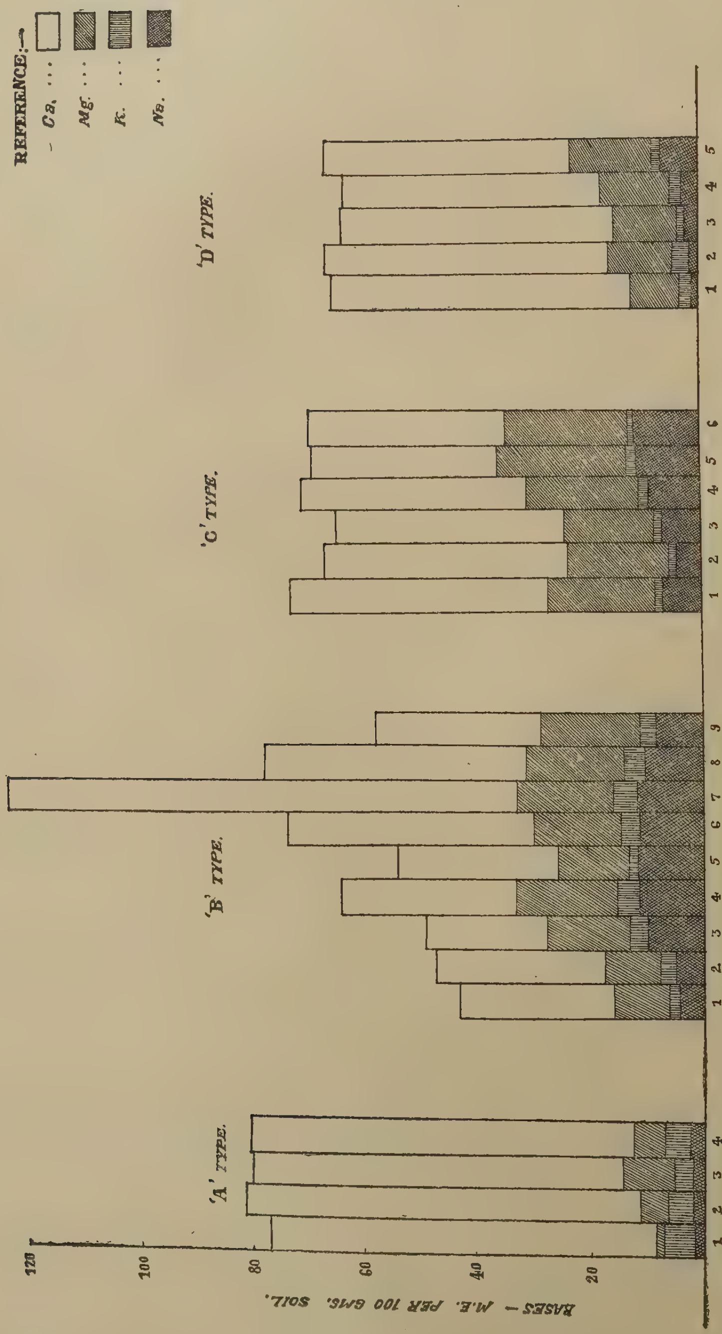


FIG. 6. Depth distribution of exchangeable bases in the profiles of different soil types

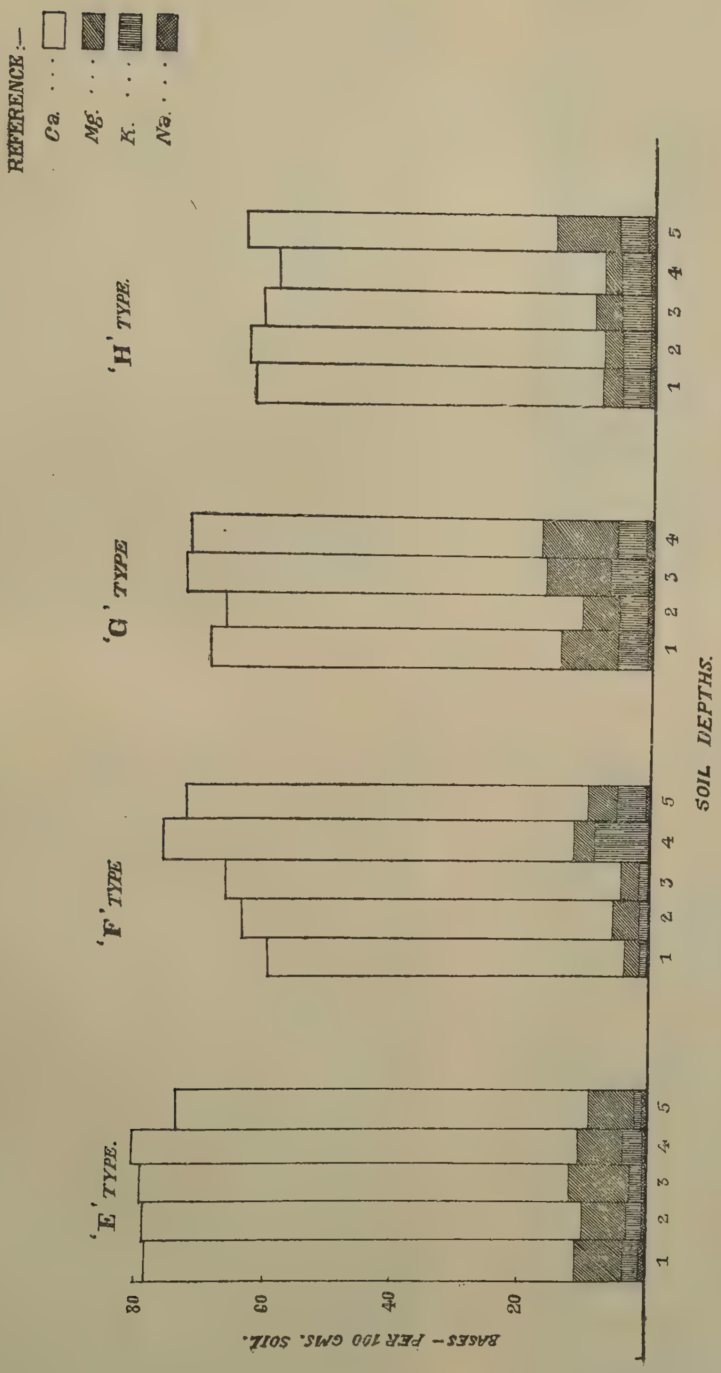


FIG. 7. Depth distribution of exchangeable bases in the profiles of different soil types

Soil type 'A'

Locality :—Malsiras, Nira Right Bank Canal.
Relief :—Very gently sloping ; on low levels.
Drainage condition :—Good.
Sub-soil water table :—At 10 to 15 feet.
General remarks :—Fallow for last six years or so—dry cultivation before ; vegetation, grasses and shrubs.

Profile (Plate LV, fig. 1) :—

Horizons			Sample depth
I	0-12 in. . .	Black soil with a tinge of red, fine crumb structure, interspersed with roots throughout ; medium clay loam ; absence of any concretions.	0-6 in. 6 in.-12 in.
II	12 in 21½ in. . .	Same as above with faint crystal-like structure appearing.	12 in.-18 in. 18 in.-21½ in.
	Below 21½ in. .	'*Murum*' or weathered rock yellowish grey, impregnated with lime ; some crystals of gypsum present.	

TABLE III

General analysis—A type

Horizon	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H		Humus (per cent)	Nitrogen per cent
						in water	in *N* KCl		
I	0-6	26·75 (29·18)	24·25 (26·45)	8·32	0·37	8·57	7·66	1·41	0·046
	6-12	33·25 (35·68)	20·75 (22·27)	6·82	0·36	8·79	7·56	1·37	0·045
II	12-18	36·00 (38·86)	25·00 (26·99)	7·36	0·38	8·66	7·59	1·26	0·048
	18-21½	30·50 (34·02)	24·50 (27·32)	10·35	0·35	8·76	7·62	0·73	0·049

The figures of clay and silt indicate that a fair amount of mechanical weathering has taken place over the entire profile with a general translocation of finer materials from the surface downwards. (Figures in brackets represent the percentages on carbonate-free basis). The soil is well supplied with calcium carbonate which shows a tendency of leaching. In spite of fair amounts of total salts, the *p*H values are appreciably high, thus indicating a high base status of the entire profile. Although the humus figures are low they are well above 1·0 per cent up to the third layer, after which there is a sudden fall. The nitrogen contents of different depths are quite uniform though low.

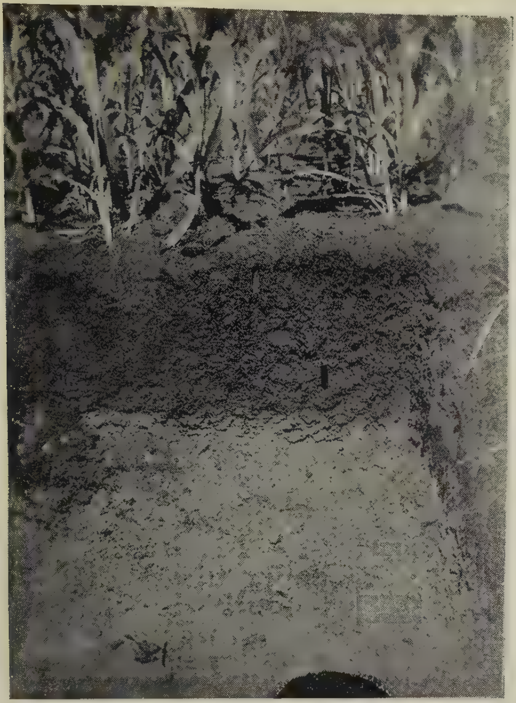


FIG. 1. Profile of soil type 'A'

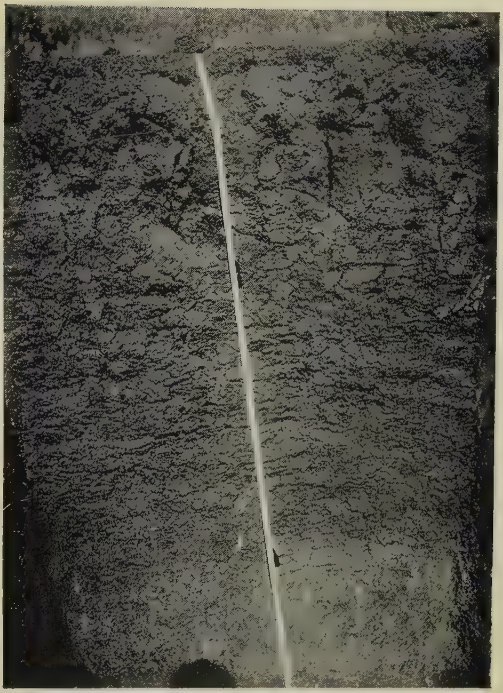


FIG. 2. Profile of soil type 'B'

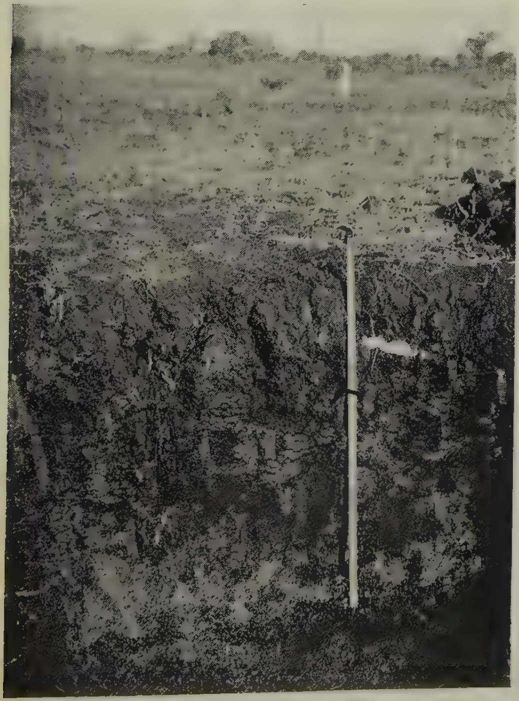


FIG. 3. Profile of soil type 'C'

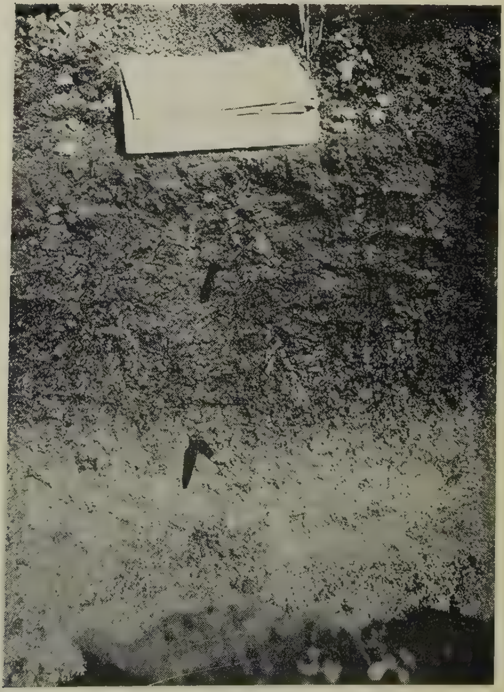


FIG. 4. Profile of soil type 'D'

TABLE IV

Bulk chemical analysis—A type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
I	0-6	6·21	47·74 (52·05)	5·50	1·28	31·59	32·87 (35·35)	10·87 (11·86)	11·68 (12·74)	0·610	0·091
	6-12	6·38	48·05 (51·54)	4·58	1·28	31·05	32·33 (34·70)	10·98 (11·78)	9·54 (10·24)	0·500	0·093
II	12-18	5·97	47·07 (50·80)	4·76	1·29	32·72	34·01 (36·68)	10·18 (10·99)	13·90 (15·01)	0·488	0·065
	18-21½	6·14	46·54 (51·91)	4·60	1·19	33·04	34·23 (38·17)	11·58 (12·92)	8·74 (9·75)	0·465	0·077

Hygroscopic moisture is fairly uniform throughout. Residue insoluble in hydrochloric acid shows the presence of almost the same amount of unweathered material in all the layers, although the clay figures in Table III indicate slight translocation towards the lower depths. Loss-on-ignition figures indicate the loss suffered by the insoluble residue, and hence represent that amount of humus and fine particles which persist after the dissolution of inorganic colloids and carbonates. In the present instance the first layer contains more humus and fine particles than the rest. Silica is collected in two stages. Firstly when it is extracted with concentrated hydrochloric acid and later (what remains) in caustic potash (page 649). It will be seen that the bulk of the silica is only extractable in caustic potash solution in the present instance. Considering the total silica on carbonate-free basis, it will be observed that there is a very gentle tendency of illuviation* of silica as well as of ferric oxide. An accumulation zone of alumina is seen in the third layer the significance of which is discussed later. There is no illuviation of either potassium oxide or phosphoric acid in the profile.

TABLE V

Derived data—molecular ratios—A type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-6	4·78	2·99	1·68	17·54
	6-12	5·75	3·30	1·35	17·56
II	12-18	4·16	2·83	2·13	26·15
	18-21½	6·61	3·60	1·20	17·56

Variations in the SiO_2/Al_2O_3 ratios in the profile are quite wide, *i.e.*, from 4·16 to 6·61. Illuviation has taken place in two stages. Similar results are observed with respect to the sesquioxides. Particularly low values of the ratio in the third layer indicate more chemical weathering, probably due to accumulation of more weathered clay in this layer. Very uniform Al_2O_3/K_2O ratios are interesting excepting in the third layer which shows a higher ratio and consequently more weathering. This Al_2O_3/K_2O ratio is likely to be of considerable interest in studying chemical weathering in arid climates, where the leaching of either silica or sesquioxides is often of negligible magnitude.

---

* Refer to 'Glossary' at the end of the paper.

TABLE VI

Exchangeable bases—A type

*(m.e. per 100 grms. soil)**

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0–6	68·50 (88·90)	1·17 (1·52)	5·66 (7·34)	1·72 (2·23)	77·05
	6–12	70·25 (86·30)	4·85 (5·96)	4·45 (5·47)	1·81 (2·22)	81·36
II	12–18	66·00 (82·10)	9·52 (11·84)	2·89 (3·59)	2·02 (2·51)	80·43
	18–21½	68·25 (84·54)	5·39 (6·69)	4·69 (5·82)	2·26 (2·80)	80·59

*Figures in brackets indicate percentage saturation with the base in each case.

The highly colloidal nature of the soil is shown by uniformly high total base saturation of the entire profile, of which calcium forms the major portion (*i.e.*, 82-89 per cent of the total). This explains the fine crumb structure of the soil. Exchangeable magnesium is very low in the first layer, but it increases with depth, showing the highest amount in the third layer. Potash exhibits an opposite tendency with a minimum in the third layer. This layer corresponds with the illuvial zone of clay. Exchange sodium is low but uniformly distributed.

Soil type 'B'

Locality :—Padegaon Farm, Nira Right Bank Canal.

Relief :—Fairly sloping.

Drainage condition :—Fair.

Sub-soil water table.—At 6 to 8 feet.

General remarks :—Fallow with occasional dry crops ; vestigation, grasses.

Profile (*Plate LV, fig. 2*) :—

Horizon	Depths in inches		Sample depths
I	0-20	Uniform dark grey with a brown shade, interspersed with roots, clay loam ; (*a*) First 9 inches with larger clods (2-3 in. dia.) (*b*) 9-20 in. smaller clods (½-1 in. dia.), more friable than above.	0-9 in. 9 in.-20 in.

Horizon	Depth in inches		Sample depths
II	20-44	Mottled horizon, brown intermingled with greyish black, brown predominating in lower layers, silt loam.	20 in.-26 in 26 in.-32 in. 32 in.-38 in. 38 in.-44 in.
III	44-60	Reddish brown colour with white concretions of lime and silicate material—more compact than above—clay.	44 in.-48 in. 48 in.-54 in. 54 in.-60 in.
	Below 60	Same as above with more of white material (tested to be $CaCO_3$). Hard *murum* at 96-in.	

Table VII

General analysis—B type

Horizons	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H in water	*p*H in *N*KCl	Humus (per cent)	Nitrogen (per cent)
I	0-9	57·00 (63·00)	11·25 (12·44)	9·61	0·30	8·79	7·46	0·95	0·048
	9-20	59·00 (64·73)	12·00 (13·16)	8·87	0·80	8·31	7·41	0·27	0·044
II	20-26	62·00 (70·30)	12·25 (13·88)	11·74	1·12	8·41	7·43	0·19	0·039
	26-32	61·75 (71·70)	12·00 (13·94)	13·87	1·58	8·57	7·33	0·31	0·038
	32-38	63·50 (70·90)	11·75 (13·12)	10·49	1·62	8·57	7·45	0·19	0·036
	38-44	5·75 (6·54)	71·75 (81·55)	12·03	1·86	8·54	7·34	0·17	0·033
III	44-48	56·25 (63·47)	13·00 (14·67)	11·38	2·06	8·31	7·44	0·13	0·023
	48-54	57·00 (69·29)	16·50 (18·74)	11·97	2·22	8·36	7·45	0·11	0·021
	54-60	61·00 (69·90)	11·75 (13·46)	12·73	1·76	8·71	7·71	0·14	0·021

Excepting the 6th layer, the soil shows high percentages of clay (Table VII) throughout the profile with a tendency to eluviation* of finer materials from the surface horizon (0-20 in.). Accumulation zones of calcium carbonate are observed in the 4th and 6th layers, whereas for total salts the illuvial horizon is noted much lower down in the profile. The percentage of total salts is very high even in the second layer (9 in.-20 in.); this may be the factor which modifies the structure of this layer when compared with the first. The very high *p*H value of the first layer clearly indicates high base saturation, especially with sodium. The *p*H values of the subsequent layers are greatly subdued, due to the presence of high percentage of soluble salts. Sudden change in the humus contents from the second layer downwards is very characteristic in this profile. Nitrogen contents, however, change more gradually.

---

*Refer to 'Glossary' at the end of the paper.

TABLE VIII

Bulk chemical analysis—B type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
I	0-9	6·38	46·33 (51·30)	5·91	6·63	2·73	9·36 (10·35)	8·07 (8·94)	11·55 (12·78)	0·313	0·042
	9-20	6·46	45·66 (50·10)	5·49	7·20	3·42	10·62 (11·66)	7·78 (8·54)	9·92 (10·89)	0·606	0·113
II	20-26	6·19	45·66 (51·73)	4·10	6·70	1·75	8·45 (9·58)	7·98 (9·04)	9·27 (10·50)	0·380	0·126
	26-32	6·31	44·28 (51·40)	3·83	6·78	3·17	9·95 (11·56)	7·78 (9·03)	9·47 (11·00)	0·410	0·130
	32-38	6·18	48·37 (54·01)	5·21	6·80	1·85	8·65 (9·66)	8·68 (9·70)	9·09 (10·15)	0·440	0·124
	38-44	6·40	46·33 (52·58)	4·12	6·99	1·74	8·73 (9·93)	8·08 (9·19)	9·34 (10·62)	0·411	0·138
III	44-48	8·10	44·60 (50·35)	3·92	6·77	1·69	8·46 (9·55)	8·38 (9·46)	8·92 (10·07)	0·358	0·133
	48-54	6·78	44·92 (51·05)	3·30	7·36	2·00	9·36 (10·64)	8·88 (10·09)	8·10 (9·21)	0·348	0·150
	54-60	6·05	47·91 (54·90)	4·17	7·22	2·65	9·87 (11·30)	9·08 (10·35)	10·47 (12·00)	0·419	0·148

Hygroscopic-moisture figures are very similar to those of A type excepting for the 7th and 8th layers where they are rather high. These high figures may be due to the presence of larger percentages of hygroscopic soluble salts. Residue insoluble in hydrochloric acid calculated on the carbonate-free basis indicates similar degree of chemical weathering throughout the profile, although the clay fraction in the 6th layer differs considerably. This will be discussed later. Loss-on-ignition figures of the 1st, 2nd and the 5th layers are higher, whereas the humus contents are only high in the 1st, 2nd and the 4th layers. The characteristic feature observed of this particular soil is its very low total silica content, of which the fraction soluble in hydrochloric acid is much greater than that soluble in caustic. potash. This indicates that the major portion of silica in this soil is present in a loose form in the crystal lattice and thus liable to easy break-down. There is eluviation of silica and ferric oxide but not of alumina. There are evidences of leaching of both potassium oxide and phosphoric acid from the surface layer (0-9 in.).

TABLE IX

Derived data—molecular ratios—B type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-9	1·37	0·95	2·22	34·24
	9-20	1·81	1·21	1·98	15·16
II	20-26	1·54	0·99	1·82	22·75
	26-32	1·77	1·16	1·90	21·14
	32-38	1·63	1·01	1·63	18·72
	38-44	1·59	1·02	1·78	20·68
III	44-48	1·61	1·01	1·67	22·90
	48-54	1·96	1·15	1·41	21·35
	54-60	1·61	1·03	1·79	23·18

Molecular SiO_2/Al_2O_3 as well as SiO_2/R_2O_3 ratios are uniformly low and suggest an extreme degree of leaching of SiO_2 in the past, comparable to those of a lateritic soil profile. A probable explanation of the existence of such a soil in an arid climate may be found in its topographic situation which has altered its soil climate (p. 641). Al_2O_3/K_2O ratios are fairly constant excepting in the first and second layers where some displacement of K_2O has taken place. These ratios, however, do not indicate the chemical weathering to be as advanced as exhibited by either SiO_2/Al_2O_3 or SiO_2/R_2O_3 ratios.

TABLE X

Exchangeable bases—B type

(*m.e. per 100 grms. soil*)

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0-9	26·25 (61·50)	10·42 (24·40)	1·97 (4·61)	4·08 (9·56)	42·72
	9-20	30·89 (64·65)	9·88 (20·66)	2·64 (5·45)	4·40 (9·20)	47·81
II	20-26	22·00 (44·90)	13·75 (28·05)	3·44 (7·02)	9·79 (19·98)	48·98
	26-32	30·50 (47·56)	18·23 (28·56)	3·76 (5·89)	11·34 (17·76)	63·83
	32-38	28·78 (53·23)	12·30 (22·74)	1·45 (2·68)	11·54 (21·34)	54·07
	38-44	44·50 (59·90)	15·09 (20·32)	3·36 (4·52)	11·28 (15·20)	74·23
III	44-48	91·25 (73·30)	17·24 (13·84)	4·48 (3·60)	11·54 (9·26)	124·51
	48-54	46·50 (59·56)	17·24 (22·17)	3·96 (5.09)	10·04 (12·92)	77·74
	54-60	28·95 (50·08)	17·42 (30·13)	3·26 (5·64)	8·16 (14·12)	57·79

The special feature of the profile is its high exchangeable sodium and low exchangeable calcium which may account for its inferior structure. The sodium saturation increases with depth from 9·56 per cent in the surface to 21·34 per cent in the fifth layer after which there is again a fall In spite of this increase in sodium saturation with depth, the high *p*H value of the surface layer is followed by lower values, which can be explained as due to the presence of a higher percentage of soluble salts in the lower layers. The high sodium saturation at the expense of the calcium base is a common occurrence in soils possessing a definite zone of accumulation of soluble salts in the profile. Exchangeable magnesium is also very high in the present instance (12 to 28 per cent of the total capacity), thus bringing down the CaO/MgO ratio considerably. Both these bases (magnesium and sodium) are likely to impart a very great impermeability to water. But this is not usually observed in the field condition, unless there is a very large percentage of exchangeable sodium in the surface layers. The higher percentages of soluble salts in the lower layers probably coagulate the highly dispersible sodium clay and make it more open and friable. The total base-saturation capacity or the residue insoluble in hydrochloric acid does not indicate any abrupt change in the sixth layer (38 in.-44 in.) as shown by the clay + silt figures. It is possible that the colloidal clay particles in this particular layer are existing as compound particles (of the size of silt) by some feebly binding material which does not, however, interfere with the usual ionic exchange reactions.

Soil type 'C'

Locality :—Khudus, Nira Right Bank Canal.
Relief :—Depression.
Drainage condition :—Impeded.
Sub-soil water table :—5 to 7 feet.
General remarks :—Fallow for about seven years—dry cultivation before ; vegetation—mainly *kunda* grass (*Ischaemum pilosum*)

Profile (Plate LV, fig. 3) :—

Depth of horizon		Sample depth
0-42 in. . .	Deep black colour without any tinge of brown, lumpy structure getting moister and stickier with depth ; black concretions of lime usually present in lower layers—clay loam.	0-6 in. 6 in.-12 in. 12 in.-18 in. 18 in.-24 in. 24 in.-30 in. 30 in.-36 in.
Below 42 in. .	Thoroughly decomposed *murum*, almost like sand, greenish yellow—heavily charged with lime concretions.	

TABLE XI

General analysis—C type

Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H		Humus (per cent)	Nitrogen (per cent)
					in water	in *N* KCl		
0-6	25·50 (26·68)	34·75 (36·35)	4·41	0·31	8·72	7·39	1·54	0·046
6-12	21·75 (22·99)	30·00 (31·71)	5·38	0·41	8·99	7·82	1·49	0·041
12-18	31·75 (33·19)	29·25 (30·57)	4·33	0·86	8·44	7·73	1·43	0·043
18-24	30·75 (32·26)	30·00 (31·47)	4·67	1·16	8·56	7·56	1·35	0·050
24-30	47·25 (49·73)	20·00 (21·05)	4·99	0·85	8·76	7·85	0·57	0·042
30-36	53·75 (57·39)	9·75 (10·41)	6·34	0·87	8·46	7·33	1·06	0·044

Although there is an eluviation of 'clay' the figures of 'silt' are fairly constant up to the 4th layer after which there is a lowering. The calcium carbonate contents are comparatively low with a slight tendency of accumulation in the second layer. The total salts show, however, a distinct zone of accumulation in the 4th layer (18 in.-24 in.). High *p*H values, in spite of the presence of large quantities of total salts, indicate the presence of large amounts of sodium colloid in the profile. There is a very gradual fall in humus from surface downwards excepting in the 5th layer. The nitrogen contents of the different layers up to *murum* are more or less constant.

TABLE XII

Bulk chemical analysis—C type

Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
0-6	5·78	54·44 (57·00)	4·70	2·08	25·25	27·33 (28·48)	9·98 (10·41)	9·97 (10·40)	0·067	0·064
6-12	5·60	55·68 (58·85)	3·92	2·28	27·85	30·13 (31·85)	12·17 (12·86)	7·28 (7·70)	0·086	0·059
12-18	5·89	51·92 (54·30)	5·86	2·19	29·62	31·81 (33·25)	11·68 (12·20)	10·67 (11·15)	0·065	0·053
18-24	5·82	53·46 (56·10)	6·06	2·20	29·51	31·71 (33·26)	12·18 (12·78)	10·30 (10·81)	0·023	0·059
24-30	5·99	51·90 (54·66)	6·04	2·18	29·90	32·08 (34·83)	12·18 (12·82)	8·77 (9·24)	0·024	0·069
30-36	5·73	52·45 (56·02)	5·16	1·98	29·41	31·38 (33·51)	12·07 (12·90)	10·33 11·30)	0·046	0·044

Figures of residue insoluble in hydrochloric acid (Table XII) are higher than normal, indicating a lesser degree of chemical weathering. Loss-on-ignition figures are higher in the lower layers, although the humus figures show a contrary result. Although the total silica for this type is lower than that of A type, the fraction soluble in hydrochloric acid is nearly double. A slight tendency of eluviation of silica is noticeable. With the exception of the first layer, where it is low, ferric oxide remains stationary over the rest of the profile. Illuviation of alumina is noticeable in the 3rd and 6th layers. The potash figures are strikingly low when compared with other soil types.

TABLE XIII

Derived data—molecular ratios—C type

Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
0-6	4·66	2·83	1·58	140·0
6-12	7·05	3·40	0·93	78·89
12-18	5·08	2·98	1·42	147·1
18-24	5·21	2·97	1·33	505·0
24-30	6·19	3·28	1·13	430·0
30-36	5·15	2·94	1·33	202·0

Both the SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios indicate a general tendency of leaching of silica up to the 5th layer. The abrupt change in these ratios in the second layer indicates a change in the composition of the clay, *i.e.*, the presence of a less weathered material is suggested here. The disturbance in the Al_2O_3/Fe_2O_3 ratios in the second layer is due to the leaching of Fe_2O_3 from the first to the second layer as well as to the presence of a low aluminium oxide figure in the latter. The Al_2O_3/K_2O ratios over the entire profile are exceptionally high, indicating an extreme condition of leaching. This is however, contradictory to our other findings, *viz.*, the high SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios as well as the presence of higher residues insoluble in hydrochloric acid, etc. These facts strongly support the view-point that this soil type must have been derived from a parent material differing considerably in chemical composition from the other soil types.

TABLE XIV

Exchangeable bases—C type

(m.e. per 100 grms. soil)

Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
0-6	46·25 (62·95)	19·93 (27·11)	0·70 (0·95)	6·59 (8·97)	73·47
6-12	43·50 (65·70)	17·87 (27·00)	0·64 (0·97)	4·17 (6·30)	66·18
12-18	41·25 (63·90)	15·89 (24·62)	0·87 (1·35)	6·53 (10·12)	64·54
18-24	41·24 (57·98)	19·93 (28·01)	0·89 (1·26)	9·09 (12·78)	71·15
24-30	34·14 (49·51)	22·99 (33·36)	0·83 (1·20)	10·97 (15·90)	68·93
30-36	35·00 (50·50)	21·83 (31·54)	0·70 (1·01)	11·74 (16·96)	69·27

This soil contains high exchange sodium and the percentage sodium saturation increases with depth as in the B type soil. It is also characterised by high magnesium saturation (27-33 per cent), and a low CaO/MgO ratio. Unlike B type, this soil possesses inferior drainage. The differences in the field behaviour may be only explained due to the fact that while B type contains a very high percentage of soluble salts in the lower layers, C type does not possess any such advantage. Exchangeable potash is much lower than either A or B type soil. (Total potash is lowest in this type.) The total base-saturation capacity is fairly uniform over the whole profile and is higher than that of B type, at least in the surface layers, in spite of lower clay contents. The high exchangeable sodium in both B and C types of soil may be accounted partly for the proximity of saline sub-soil water.

Soil type 'D'

Locality :—Akluj, Nira Righ Bank Canal.

Relief :—Undulating, but on lower levels.

Drainage condition :—Good.

Sub-soil water table :—At 15 to 20 feet.

General remarks :—Dry cultivation.

Profile (Plate LV, fig. 4) :—

Horizon	Depth of horizons		Sample depth
I	0-12 in.	Dark grey with brown shade—loose and granular soil with faint structure appearing in lower horizons (from 12 in. downwards), which attains distinct lamination in the lowest layer.	0-6 in. 6-12 in. 12 in.-18 in. 18 in.-24 in. 24 in.-30 in.
II	12-30 in.		
	Below 30 in.	Lime band—dirty white colour—of varying depths (6 in. to 5-6 ft. occasionally), intervenes between the soil horizon and *murum* below.	

TABLE XV

General analysis—D type

Horizon	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	pH		Humus (per cent)	Nitrogen (per cent)
						in water	in N KCl		
I	0-6	55·75 (61·55)	15·75 (17·39)	9·42	0·23	8·94	7·67	1·32	0·042
	6-12	57·50 (65·10)	16·00 (18·12)	11·68	0·23	8·81	7·87	1·26	0·044
II	12-18	56·75 (62·27)	14·50 (15·91)	8·86	0·25	9·01	7·77	1·22	0·046
	18-24	54·50 (59·17)	11·75 (12·76)	7·90	0·20	9·01	7·81	1·21	0·050
	24-30	56·00 (59·67)	20·50 (21·84)	6·15	0·23	9·01	7·76	1·19	0·047

The percentage of clay (Table XV) is very high but this is not manifested by field observation of the soil profile. The figures of clay and silt do not exhibit any mechanical differentiation in different layers. A tendency of accumulation of calcium carbonate towards the surface is noticeable in the depth distribution of this particular ingredient. The presence of a fairly high amount of dispersed materials is denoted by the high pH values of the entire profile. While the low total salt contents aggravate dispersion of colloidal material, the presence of a larger percentage of humus probably acts as a binding material in the formation of stable soil crumbs.

TABLE XVI

Bulk chemical analysis—D type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
I	0-6	5·71	48·65 (53·54)	3·30	1·59	29·75	31·34 (34·60)	10·48 (11·56)	9·91 (10·94)	0·588	0.067
	6-12	5·60	48·71 (54·90)	2·02	1·48	30·45	31·93 (35·96)	9·78 (11·08)	10·67 (12·08)	0·476	0·062
II	12-18	5·50	49·22 (54·00)	6·46	1·25	32·48	33·73 (37·00)	9·58 (10·51)	12·27 (13·46)	0·392	0·081
	18-24	6·18	50·07 (54·40)	4·50	1·37	31·22	32·59 (35·40)	9·78 (10·62)	12·50 (13·58)	0·610	0·066
	24-30	2·23	50·00 (53·29)	4·50	1·31	33·40	34·71 (36·97)	10·18 (10·85)	11·39 (12·14)	0·625	0·095

The very low figure for hygroscopic moisture (Table XVI) of the 5th layer cannot be explained from the mechanical composition of the soil. Residue insoluble in HCl shows the presence of larger amounts of chemically unweathered material although the physical disintegration must have proceeded very far as can be seen from the figures of 'clay' and 'silt'. Figures of loss on ignition are higher from the third layer downwards. The total silica shows slight eluviation while ferric oxide does not exhibit any such tendency. Alumina, however, demonstrates a feeble zone of accumulation in the 4th layer. The distribution of potassium oxide is rather irregular in the present instance.

TABLE XVII

Derived data—molecular ratios—D type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-6	5·37	3·19	1·47	15·64
	6-12	5·10	3·21	1·71	20·38
II	12-18	4·67	3·11	2·00	28·57
	18-24	4·44	2·96	2·00	18·76
	24-30	5·19	3·29	1·73	16·62

Molecular SiO_2/Al_2O_3 ratio falls off with depth, which indicates that a fundamental change must have taken place in the way of translocation of more chemically weathered fraction of the soil without mechanical eluviation. Similar indications are obtainable from the SiO_2/R_2O_3 ratios. The constancy of the Al_2O_3/Fe_2O_3 ratio is clearly disturbed as a result of the above chemical weathering. In a highly alkaline medium, such as obtains in the present profile, the stability of the silicate complex is likely to be weakened considerably. The products of disintegration, however, will have differential mobility, aluminium being easily mobilised in the presence of excess of alkali bases (liberated as a result of decomposition), whereas iron, forming insoluble hydroxides, remains in the seat of reaction. From the figures in the last column it is apparent that the loss of potassium oxide undergone by the soil during the process of soil-formation increases with depth up to the third layer.

TABLE XVIII

Exchangeable bases—D type

(m.e. per 100 grms. soil)

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0-6	52·50 (80·44)	8·81 (13·50)	2·60 (3·98)	1·34 (2·05)	65·25
	6-12	49·75 (75·50)	11·86 (17·95)	2·52 (3·82)	1·78 (2·70)	65·91
II	12-18	48·45 (76·65)	11·24 (17·78)	1·26 (1·99)	2·23 (3·53)	63·18
	18-24	46·40 (73·55)	12·22 (19·38)	1·74 (2·76)	2·71 (4·30)	63·07
	24-30	44·35 (66·90)	14·46 (21·65)	1·27 (1·92)	6·21 (9·37)	66·29

Although the total base-saturation figures are fairly uniform in all the layers, there is considerable variation in the amounts of different bases in the different layers. Thus, while exchangeable sodium increases with depth, exchangeable calcium falls off progressively. Exchangeable potash and magnesium also show such inverse relationship, magnesium increasing while potassium diminishing with depth. Thus the resultant effect is the inferior structure and inferior drainage condition of the lower layers. The higher percentage of sodium in the lower layers, in spite of the shallow depth, may be explained as follows :—

The soluble products of weathering (mainly sodium salts) are not completely removed into the *murum*, due to the presence of the intermediate lime band (composed mainly of calcium carbonate) which converts the sodium salts into reactive sodium carbonate which in drier periods travels upwards and affects the lower layers converting calcium soil into sodium soil. The higher *p*H values of the soil may be due partially to the presence of free sodium carbonate in this soil. (Suspensions in distilled water give distinct pink coloration with phenolphthalein in the last three layers only.)

Soil type 'E'

Locality :—Mahalung, Nira Right Bank Canal.

Relief :—Low lying areas. Soils are deeper on the ridges than on the slopes in the present instance.

Drainage condition :—Fair,

Sub-soil water table :—At 15 to 20 feet.

General remarks :—Dry cultivation.

Profile (*Plate LVI, fig. 1*) :—

Horizon	Depth		Sample depth
I	0-12 in.	Dull greyish black, loose and granular, interspersed with roots—loam	0-6 in. 6 in.-12 in.
II	12 in.-30 in.	Slightly darker in colour, definitely more compact, with a tendency to horizontal lamination—hardly any roots visible—clay loam.	12 in.-18 in. 18 in.-24 in. 24 in.-30 in.
	Below 30 in.	*Murum*, grey and yellow with glauconite, no lime deposition visible.	

Table XIX

General analysis—E type

Horizon	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H		Humus (per cent)	Nitrogen (per cent)
						in H_2O	in *N*KCl		
I	0-6	61·50 (67·31)	9·25 (10·12)	8·63	0·24	8·64	7·71	1·52	0·053
	6-12	62·25 (68·32)	10·50 (11·52)	8·89	0·20	8·63	7·71	1·57	0·053
II	12-18	59·75 (65·77)	12·00 (13·21)	9·16	0·37	8·57	7·71	1·42	0·051
	18-24	59·00 (63·69)	11·25 (12·14)	7·36	0·28	8·59	7·69	1·51	0·053
	24-30	62·25 (68·34)	13·00 (14·27)	8·91	0·25	8·59	7·66	1·48	0·056

Although the percentage of clay (Table XIX) is uniformly very high throughout the profile, the loose and granular structure of the surface horizon (0-12 in.) and a well-defined change into the compact and laminated nature of the second horizon are not explainable. Faint zones of accumulation of both calcium carbonate and total salts are noticeable in the 12 in.-18 in. layer which may indicate a certain amount of impedence exerted by the compact second horizon. The *p*H values of the first two layers are slightly higher than those of the next three layers. The humus and nitrogen figures are fairly uniform in different layers.

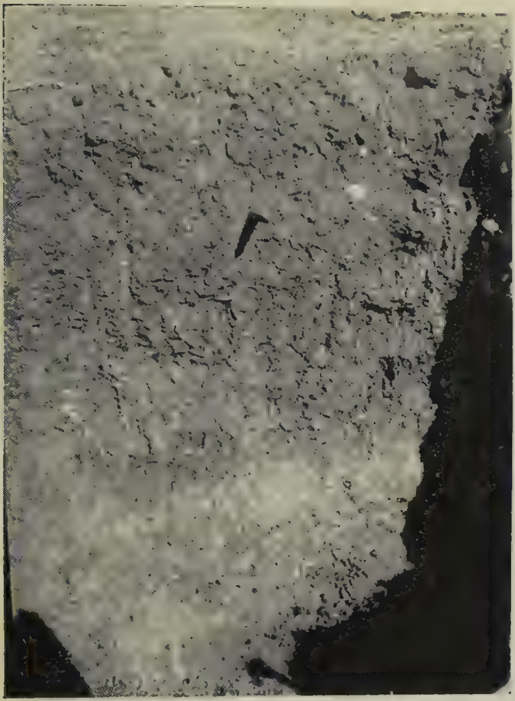


FIG. 1. Profile of soil type 'E'

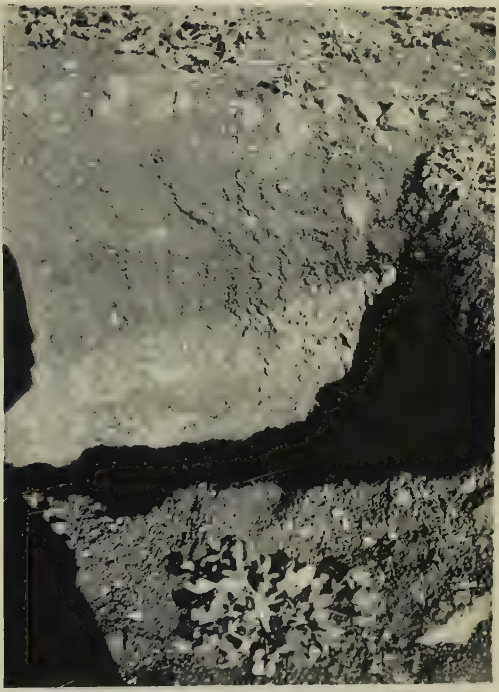


FIG. 2. Profile of soil type 'F'

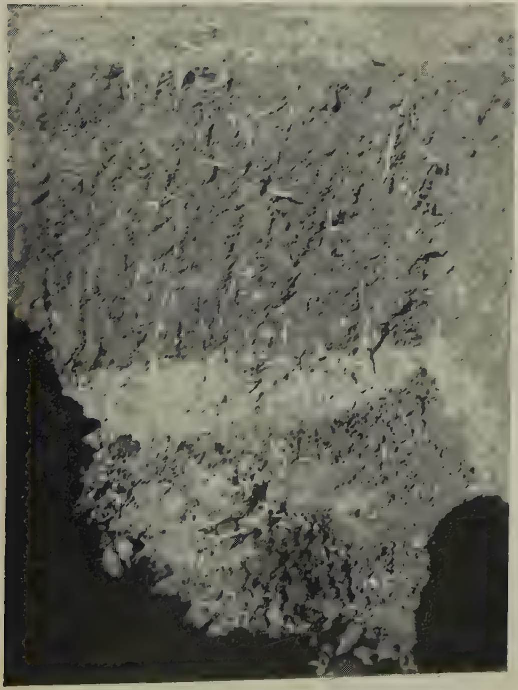


FIG. 3. Profile of soil type 'G'

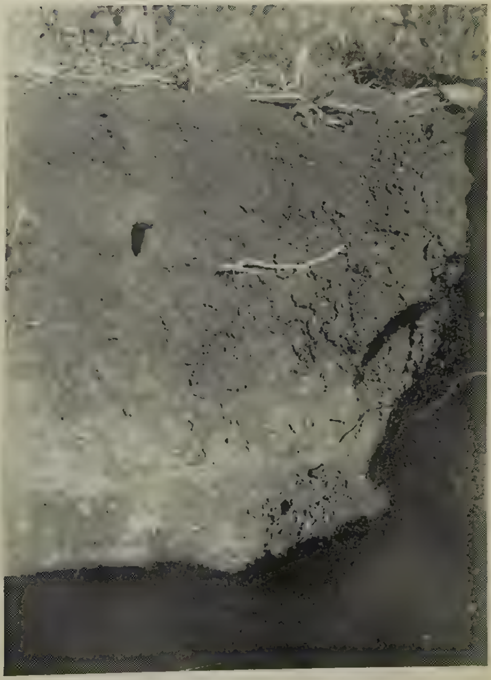


FIG. 4. Profile of soil type 'H'

TABLE XX

Bulk chemical analysis—E type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
I	0-6	6·38	48·36 (52·90)	4·64	1·71	32·44	34·13 (37·33)	11·08 (12·12)	10·97 (12·00)	0·976	0·092
	6-12	7·26	48·65 (53·40)	4·60	1·66	32·82	34·48 (37·85)	10·78 (11·84)	9·42 (10·34)	0·952	0·064
II	12-18	6·67	47·86 (52·65)	5·62	1·60	33·14	34·74 (38·24)	10·29 (11·32)	9·63 (10·60)	1·112	0·076
	18-24	6·77	48·34 (52·19)	4·68	1·33	29·92	31·25 (33·73)	9·58 (10·34)	8·10 (8·74)	0·179	0·069
	24-30	6·43	47·85 (52·50)	5·70	1·66	30·54	32·20 (34·37)	11·18 (12·28)	10·67 (11·72)	0·417	0·074

The higher hygroscopic moisture figures (Table XX) are consistent with the higher percentages of clay in the soil. Residue insoluble in hydrochloric acid indicates a slightly lower degree of chemical weathering than that of A type although the clay figures in the present instance are much higher. Loss-on-ignition figures for the 3rd and 5th layers are slightly higher. In the present case no eluviation of silica, ferric oxide or alumina can be traced excepting in the last layer where the sesquioxides are present in a slightly higher proportion. The percentages of potassium oxide are much higher than the types described already and an eluviation of this constituent is also noticeable in the 12 in.-18 in. layer.

TABLE XXI

Derived data—molecular ratios—E type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-6	5·29	3·20	1·53	10·29
	6-12	6·22	3·60	1·37	9·11
II	12-18	6·13	3·65	1·47	7·97
	18-24	6·56	3·73	1·32	41·58
	24-30	5·14	3·07	1·49	23·64

The ratios of SiO_2/Al_2O_3 and SiO_2/R_2O_3 show that the intensity of chemical weathering has gone down with depth as is characteristic of a soil formed *in situ* although the lowest layer seems to have been enriched by illuviation of some chemically weathered material. The Al_2O_3/K_2O ratios are the lowest in this profile, thus pointing out that the chemical reaction in this case has not proceeded as far as in other soil types. This is also corroborated by the higher SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios of the soil layers.

TABLE XXII

Exchangeable bases—E type

(*m.e. per 100 grms. soil*)

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0-6	68·75 (87·48)	7·18 (9·13)	1·67 (2·12)	1·03 (1·31)	78·63
	6-12	70·25 (88·65)	7·01 (8·85)	1·24 (1·57)	0·74 (0·93)	79·24
II	12-18	69·25 (86·95)	8·26 (10·37)	1·58 (1·98)	0·54 (0·68)	79·63
	18-24	69·50 (86·25)	7·19 (8·93)	3·30 (4·10)	0·58 (0·72)	80·57
	24-30	65·60 (88·30)	7·01 (9·44)	1·15 (1·55)	0·53 (0·71)	74·29

High base-saturation capacity of the soil is accompanied by high clay figures of the entire profile. The sharp change in the structure profile as observed in the field is neither reflected in the depth distribution of any of the exchangeable bases nor in the distribution of clay. It is more than likely that long-continued dry cultivation has affected the surface horizon by making it loose and friable, so that the root penetration is limited to this depth without altering either the chemical or mechanical composition of the soil. Impeded drainage of the soil as well as the heavy structure can only be accounted for by the presence of high clay and high exchangeable magnesium of the soil as the exchangeable sodium is very low throughout.

Soil type 'F'

Locality :—Durgapur, Pravara Left Bank Canal.

Relief :—Sloping with a fair amount of gradient on high levels.

Drainage condition :—Fair.

Sub-soil water table :—At 15 feet.

General remarks :—Dry cultivation—crop, *bajri*.

Profile (Plate LVI, fig. 2):—

Horizon	Depth of horizon		Sample depth
I	0-8 in.	Light brown colour, loose and granular structure with pieces of *murum*; loam.	0-4 in. 4 in.-8 in.
II	8 in.-15 in.	Darker in colour than above with a greyish shading, compacted, with structure (breaks up into shiny crystal-like particles)—absence of *murum*, this horizon is of variable depth—penetration of roots less intense—clay loam.	8 in.-10½ in. 10½ in.-12½ in. 12½ in.-15-in.
Below	15.in.	Hard *murum*, grey with yellow specks with occasional incrustation of lime.	

TABLE XXIII

General analysis—F type

Horizon	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H		Humus (per cent)	Nitrogen (per cent)
						in H_2O	in *N* KCl		
I	0-4	45·50 (45·99)	22·50 (22·74)	1·07	0·39	8·17	7·49	0·59	0·058
	4-8	49·00 (49·72)	21·25 (21·56)	1·44	0·40	8·05	7·39	0·61	0·056
II	8-10½	54·25 (55·53)	21·25 (21·75)	2·30	0·42	8·09	7·57	0·48	0·055
	10½-12½	56·50 (58·31)	16·50 (17·03)	3·10	0·46	8·05	7·59	0·51	0·058
	12½-15	55·75 (58·58)	18·00 (18·91)	4·83	0·43	8·05	7·59	0·64	0·060

Increased proportion of clay (Table XXIII) found in the second horizon (8 in.-15 in.) tallies well with the field observation of the profile. Although a sharp eluviation of calcium carbonate is noticed there is no zone of accumulation present. The total salt content is fair considering the shallowness of the profile, which indicates that the drainage condition is not as good as could be expected from its depth. It can be inferred from the low *p*H values that the soil is mainly composed of calcium base with very little sodium in the complex. The higher nitrogen contents may be ascribed to the rapid recuperative powers of these shallow soils.

TABLE XXIV

Bulk chemical analysis—F type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
I	0-4	4·1	54·96 (55·58)	4·19	2·50	26·14	28·64 (28·96)	14·64 (14·80)	10·71 (10·83)	0·187	0·360
	4-8	4·2	54·39 (55·20)	4·41	2·61	25·22	27·83 (28·24)	14·76 (14·98)	7·22 (7·32)	0·180	0·350
II	8-10¼	4·7	53·41 (54·70)	4·62	2·05	26·40	28·45 (29·13)	13·66 (13·98)	7·29 (7·46)	0·185	0·339
	10¼-12½	5·4	52·75 (54·95)	4·57	2·19	27·19	29·38 (30·33)	13·29 (13·72)	7·19 (7·42)	0·201	0·344
	12½-15	6·5	52·68 (55·39)	4·63	1·94	27·70	29·64 (31·15)	13·06 (13·72)	8·72 (9·16)	0·196	0·311

The hygroscopic moisture (Table XXIV) increases steadily with depth, showing the increase in the colloidal material. The figures of residue insoluble in hydrochloric acid indicate the presence of more of the chemically unweathered material in the soil. The loss-on-ignition figures are higher for the 2nd horizon (8 in.-15 in.) than the first (0-8 in.) which may be due entirely to the mechanical nature of the profile. The proportion of total silica is lower than usual, although the fraction coming in the HCl extract is higher than normal. A slight leaching tendency of this constituent is, however, observed which is absent in the case of the sesquioxides. The potash contents are lower and the phosphate higher than normal in all the layers of this soil.

TABLE XXV

Derived data—molecular ratios—F type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-4	4·53	2·41	1·14	52·50
	4-8	6·49	2·83	0·86	41·60
II	8-10½	6·65	3·01	0·83	35·50
	10½-12½	6·96	3·18	0·84	33·34
	12½-15	5·79	2·95	1·04	40·50

Both the SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios become wider with depth up to the 4th layer, pointing out that the intensity of chemical weathering diminishes with depth, in spite of mechanical eluviation of clay downwards. Some translocation of chemically decomposed clay is evidenced only in the last layer. The first 4 in. of soil seem to be intensely affected by chemical reaction. Abnormally low Al_2O_3/Fe_2O_3 ratios over the entire profile is a characteristic feature of this soil. The Al_2O_3/K_2O ratios are also higher than the types described before.

TABLE XXVI

Exchangeable bases—F type

(*m.e. per 100 grms. soil*)

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0-4	56·50 (94·28)	2·34 (3·90)	0·75 (1·26)	0·35 (0·58)	59·94
	4-8	58·30 (91 20)	4·50 (7·04)	0·82 (1·28)	0·29 (0·45)	63·91
II	8-10½	62.35 (93·20)	2·59 (3·88)	1·39 (2·08)	0·38 (0·57)	66·71
	10½-12½	64·22 (83·96)	3·67 (4·80)	8·19 (10·71)	0·41 (0·54)	76·49
	12½-15	63·36 (86·45)	4·83 (6·59)	4·59 (6·27)	0·46 (0·63)	73·24

The eluviation of clay in the profile corresponds with increasing base-saturation capacity of the soil. Per cent calcium saturation of the first three layers are very high (91 to 94 per cent) after which there is a lowering in the values (84 to 86 per cent). The exchange magnesium, however, increases in the second and fifth layers to some extent, whereas potash is only high in the fourth and fifth layers. Exchangeable sodium is throughout very low. Thus although there is a general indication of an inferior structure and drainage condition in the lower layers, the more compact nature of the second horizon is only explained by higher clay contents of this horizon (8 in.-15 in.)

Soil type 'G'

Locality :—Bhokar, Pravara Left Bank Canal.
Relief :—Flat or gently sloping ; on higher levels.
Drainage condition :—Good.
Sub-soil water table :—At 8 to 12 feet.
General Remarks.:—Dry cultivation.
Profile (*Plate LVI, fig. 3*) :—

Horizon	Depth		Sample depth
I	0-13 in.	Dark brown colour, crumby structure—crumbs breaking up into small grains under pressure —occasional concretions of lime—loam.	0-6½ in. 6½ in.-13 in.
II	13 in.-24 in.	Similar in colour with faint crystal-like structure appearing, concretions of lime and *murum* particles increasing with depth—loam	13 in.-18½ in. 18½ in.-24 in.
	Below 24 in.	*Murum*, pinkish in colour, coated with lime, fairly weathered with horizontal cleavage ; amygdales present.	

TABLE XXVII

General analysis—G type

Horizon	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H		Humus (per cent)	Nitrogen (per cent)
						in H_2O	in *N* KCl		
I	0-6½	52·25 (54·68)	14·50 (15·17)	4·44	0·18	8·29	7·74	0·78	0·053
	6½-13	55·25 (58·94)	9·25 (9·87)	6·26	0·17	8·23	7·74	0·72	0·048
II	13-18½	55·00 (58·99)	11·50 (12·33)	6·76	0·25	8·16	7·74	0·65	0·050
	18½-24	55·50 (59·61)	10·75 (11·55)	6·90	0·26	8·17	7·69	0·82	0·054

Mechanical composition (Table XXVII) (*i.e.*, clay+silt on carbonate-free basis) is fairly uniform, the second horizon (13 in.-24 in.) showing slightly higher proportion of finer materials which may partly explain its faint structure development. Leaching down of calcium carbonate is very gentle in the present case. The first horizon (0-13 in.) contains a lower percentage of salts and has a slightly higher *p*H value. The humus and nitrogen contents are moderate in this soil.

TABLE XXVIII

Bulk chemical analysis—G type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent.	P_2O_5 (per cent)
I	0-6½	4·4	55·80 (58·38)	6·23	1·59	29·93	31·52 (33·13)	10·20 (10·68)	10·50 (10·83)	0·192	0·305
	6½-13	4·5	54·64 (58·30)	6·51	1·64	29·00	30·64 (32·68)	9·30 (9·92)	8·30 (8·86)	0·189	0·324
II	13-18½	4·7	53·90 (57·82)	5·27	1·52	30·20	31·72 (34·03)	10·00 (10·73)	9·40 (10·08)	0·381	0·299
	18½-24	5·9	52·33 (56·20)	5·93	1·61	28·80	30·41 (32·65)	9·40 (10·10)	8·80 (9·45)	0·143	0·284

The residue insoluble in hydrochloric acid (Table XXVIII) indicates more of chemical weathering with increasing depth. The third layer (13 in.-18½ in.) seems to be slightly enriched by silica, sesquioxides and potash.

TABLE XXIX

Derived data—molecular ratios—G type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-6½	4·91	3·01	1·58	50·50
	6½-13	5·94	3·46	1·40	40·50
II	13-18½	5·45	3·23	1·46	23·00
	18½-24	5·56	3·30	1·46	57·30

From the SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios it is apparent that the first layer (0-6½ in.) is most intensely leached. The third layer of the soil does not show any abnormal ratio (when compared with the rest) of either SiO_2/Al_2O_3, SiO_2/R_2O_3 or Al_2O_3/Fe_2O_3 as the respective accumulations of these three constitutents seem to be in the same proportion. The potash, however has been leached from the surface layers to a much greater degree than Al_2O_3,

TABLE XXX

Exchangeable bases—G type

(m.e. per 100 grms. soil)

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0-6½	55·37 (79·70)	8·67 (12·48)	4·89 (7·04)	0·56 (0·81)	69·49
	6½-13	55·37 (83·07)	6·09 (9.13)	4·73 (7·09)	0·52 (0·78)	66·71
II	13-18½	56·88 (77·25)	10·38 (14·09)	5·80 (7·87)	0·47 (0·64)	73·53
	18½-24	55·50 (76·30)	11·81 (16·24)	4·53 (6·23)	0·88 (1·21)	72·72

There is very little difference in the base-saturation capacity or exchangeable calcium in different layers. Both exchange magnesium (9 to 16 per cent saturation) and potassium (6 to 8 per cent saturation) are fairly high, the former being present in slightly higher amount in the second horizon (13 in. 24 in.). The low CaO / MgO ratio indicates a general inferior drainage condition of the soil. Exchangeable sodium is, however, fairly low.

Soil type 'H'

Locality :—Loni *Khurd*, Pravara Left Bank Canal.

Relief :—Slightly sloping ; higher level.

Drainage condition :—Very good.

Sub-soil water table :—At 12 feet.

General remarks :—Dry cultivation.

Profile (*Plate LVI, fig. 4*) :—

Horizon	Depth		Sample depth
I	0-8 in.	Reddish brown colour—porous and granular. Does not effervesce with dil. HCl—loam	0 in.-4 in. 4 in.-8 in.
II	8 in.-16 in.	Chocolate brown colour—with faint structure. Penetration of roots visible up to this horizon only. Effervesces with dil. HCl—loam.	8 in.-12 in. 12 in.-16 in.
III	16 in.-19 in.	Same colour as above, slightly compacted with presence of lime and *murum* ; clay loam.	16 in.-19 in.
	Below 19 in.	*Murum* thoroughly disintegrated, greenish yellow with heavy incrustation of lime carbonate.	

TABLE XXXI

General analysis—H type

Horizon	Depth in inches	Clay (per cent)	Silt (per cent)	$CaCO_3$ (per cent)	Total salts (per cent)	*p*H		Humus (per cent)	Nitrogen (per) cent)
						in H_2O	in *N* KCl		
I	0-4	46·00 (46·26)	15·25 (15·34)	0·56	0·25	8·35	7·77	0·69	0·048
	4-8	47·00 (47·49)	12·50 (12·63)	1·04	0·42	8·51	7·63	0·55	0·058
II	8-12	52·50 (53·30)	13·25 (13·46)	1·53	0·48	8·14	7·57	0·41	0·052
	12-16	52·50 (55·40)	12·25 (12·93)	5·24	0·33	8·33	7·67	0·39	0·044
III	16-19	47·50 (51·30)	14·75 (15·93)	7·41	0·25	8·26	7·66	0·44	0·046

There is a sharp change in the clay content (Table XXXI) while going from the first to the second horizon although the structure is not well differentiated. The depth distribution of calcium carbonate indicates profuse leaching. A slight accumulation of salts has taken place in the third layer where the *p*H value is also lowest. The humus content diminishes progressively with depth.

TABLE XXXII

Bulk chemical analysis—H type

Horizon	Depth in inches	Moisture (per cent)	Residue insoluble in HCl (per cent)	Loss on ignition (per cent)	SiO_2 soluble in HCl (per cent)	SiO_2 soluble in KOH (per cent)	Total SiO_2 (per cent)	Fe_2O_3 (per cent)	Al_2O_3 (per cent)	K_2O (per cent)	P_2O_5 (per cent)
I	0-4	3·4	61·27 (61·65)	5·51	1·83	28·01	29·84 (30·02)	11·40 (11·46)	9·85 (9·91)	0·150	0·293
	4-8	4·3	61·29 (61·92)	5·67	1·83	27·92	29·75 (30·07)	11·10 (11·22)	8·18 (8·27)	0·133	0·264
II	8-12	4·7	59·17 (60·10)	5·21	1·70	28·85	30·55 (31·03)	10·70 (10·87)	12·20 (12·39)	0·024	0·314
	12-16	6·6	57·90 (61·12)	5·23	1·63	27·73	29·36 (30·99)	10·20 (10·77)	10·85 (11·45)	0·143	0·327
III	16-19	6·1	55·08 (59·50)	4·84	1·30	27·74	29·04 (31·37)	9·50 (10·26)	10·95 (11·82)	0·110	0·323

The increase in colloids with depth (Table XXXII) is indicated by the figures of the hygroscopic moisture. The figures of residue insoluble in hydrochloric acid suggest that the first horizon (0-8 in.) contains more of unweathered materials than the second (8 in.-16 in.) and the third horizon (16 in.-19 in.). Loss-on-ignition figures do not show any significant variation. The silica is uniformly distributed over the whole profile. The first horizon is richer in ferric oxide and poorer in alumina, whereas the reverse is true for the other horizons. There is a sudden drop in the potassium oxide content of the third layer which reflects a more leached condition.

Table XXXIII

Derived data—molecular ratios—H type

Horizon	Depth in inches	SiO_2/Al_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3	Al_2O_3/K_2O
I	0-4	4·94	2·81	1·32	58·75
	4-8	5·72	3·09	1·14	57·15
II	8-12	4·03	2·58	1·78	396·7
	12-16	4·34	2·71	1·66	70·70
III	16-19	4·30	2·76	1·78	89·20

From the SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios it is apparent that the second and the third horizons seem to be in a more advanced stage of chemical decomposition than the first horizon. Of the different layers, the third one is affected most as will be evident from the Al_2O_3/K_2O ratios also. The lower Al_2O_3/Fe_2O_3 ratios of the first horizon may explain the characteristic reddish-brown colour of the surface soil as due to the presence of free oxides of iron, as a result of irreversible dehydration of hydroxides of iron at high temperatures.

TABLE XXXIV

Exchangeable bases—H type

(*m.e. per 100 grms. soil*)

Horizon	Depth in inches	Ca	Mg	K	Na	Total base-saturation capacity
I	0-4	54·12 (86·37)	3·85 (6·14)	4·33 (6·91)	0·39 (0·62)	62·69
	4-8	55·75 (87·58)	3·22 (5·06)	4·25 (6·68)	0·43 (0·68)	63·65
II	8-12	52·10 (84·90)	4·21 (6·86)	4·60 (7·49)	0·49 (0·80)	61·40
	12-16	51·72 (87·29)	2·68 (4·52)	4·17 (7·04)	0·67 (1·13)	59·24
III	16-19	48·97 (76·30)	9·85 (15·35)	4·49 (7·00)	0·86 (1·34)	64·17

In spite of higher percentage of clay in the second horizon the total base-saturation capacity seems to be more or less alike in all the three horizons. Per cent saturation with calcium (84-87 per cent), magnesium (4·5 to 6·8 per cent), potassium (6·6 to 7·5 per cent) and sodium (0·62 to 1·13 per cent) seem to be similar in both the first and second horizons, while the third horizon contains lower calcium (76·3 per cent) but higher magnesium (15·35 per cent). The slightly compact nature of the third horizon may be explained due to this fact. The second horizon, however, in spite of higher clay content, does not indicate any degree of compaction.

In the foregoing data the employment of the HCl extract of the soil for the determination of the silica and sesquioxides necessary for the evaluation of the processes involved in soil genetics may require an explanation. As already explained in the section under laboratory methods (p. 648), the method is in general vogue on the European continent. It owes its origin to the Russian school of pedologists but has been current for a number of years in a modified form as the van Bemmelen-Hissink method. The Third Commission of the International Society of Soil Science at Budapest in 1927 recommended the method, with certain improvements worked out as suggested by a previous Commission, as the official International method. Dr. A. A. J. de'Sigmond [1927], as President of this Commission, in emphasising the merits of this procedure, wrote: "Though evidence was presented that the soil extract prepared with concentrated hydrochloric acid does not represent a natural limit of soil decomposition, the total analysis of the acid extract, supplemented by the re-solution of the silica, decomposed and partly precipitated by the strong acid, by a dilute solution of alkali, will serve as a good guide in characterising soil types, especially if we investigate each typical horizon of the soil profile.'' The method was subsequently accepted as the official International method.

More recent investigations, however, tend to lay stress on the analysis of the clay fraction rather than that of the entire soil. Crowther [1930] has pointed out that as the different mechanical fractions are usually in different stages of weathering, " a combination of physical fractionation with chemical and mineralogical analyses of the fractions is desirable, but (that) for many purposes a chemical analysis of the finest fraction of mechanical analysis proves sufficient.'' Robinson [1932], however, thinks that " certain tropical soils may, indeed, contain material of secondary origin in the fractions other than the clay ". It was therefore considered the best course to resort to the acid-extract of the whole soil in the first instance to be able to compare the results with the Continental soil literature mainly on which a world group classification has been made, and in addition, to take up clay fraction analysis to determine whether for the soils under consideration it would be possible in future to restrict to any one of these analyses. The clay-fraction analysis has already been taken in hand and will be reported in a later publication.

IV. General discussion

In the foregoing discussions the distinguishing characteristics of different soil types have been fully described with special reference to their morphology and field differentiation. The present discussions will be limited to a consideration of the more important factors of soil formation and their bearing on the profile development.

Moisture relationships in soils and the morphology of the soil types.—Study of the eluviation of soluble salts in a soil profile affords a reliable index of general moisture relationships in soils. Thus a soil profile indicating a zone of accumulation of soluble salts remains moist for considerably more time during a year than a soil profile without any such accumulation zone, as in an arid climate the latter can only take place when the depth of the soil is insufficient to hold all the rain water within its soil mass. Two very of profound changes are thus brought about in the soil : (1) The weathering products are not altogether lost from the soil but there is always a differential separation of soluble salts which in time may cause alkalinisation of certain parts of the profile. (2) The products of soil-weathering are removed out of the soil mass without any chance of their returning by capillary forces. The soils in the former case invariably contain a higher percentage of exchangeable sodium and when this takes place in the surface horizon, the soil assumes a hard and lumpy structure which is very difficult to break. Even when the exchangeable sodium on the surface is not very high the soils of this group exhibit clod-like structure when dry but which can be broken up into its component crumb structure. This lumpy or clod-like structure of the surface soil is, however, not to be found in soils where the zones of accumulation of soluble salts are not present. In case (2) cited above two sets of soil-forming processes may be distinguished: (*a*) soils without zones of accumulation of salts found on higher levels, (*b*) soils without zones of accumulation of salts found on low levels. In the second case the soils may remain moist for a longer period than in the first, due to the topographic situation (as the rain falling on higher areas collects and passes over the low-lying soils as run-off water, thus increasing the effective rain considerably). The salts washed down from higher slopes also minimise the effect of leaching in these soils considerably. Weeds grow more profusely in these soils, thus adding more humus to the soil and also protecting the soil from attaining very high temperatures in summer (thus probably avoiding the breakdown of the soil complex to a considerable extent). Thus these soils on the low level (A, D and E types) contain more humus, calcium carbonate, total salts, higher *p*H values and also higher total potash and a black colour when compared with the soils on high level (F, G and H types) where the colour is brown. The structure of the latter group of soils is represented by finer grained crumbs when compared with the former (low-lying soils) and thus the low-lying soils without zones of accumulation of salts possess intermediate property between the soils with a zone of accumulation of salts and the high level soils without a zone of accumulation of salts due to the characteristics of the moisture conditions of these soils resulting from the topograhic condition, depth and drainage of the soil. The depth of soil in the present instance may therefore be defined genetically by the characteristic eluviation of soluble salts.

Development of soil horizons and their bearing on agriculture.—The importance of the elements of topography on the soil-forming processes has been already pointed out. The development of the soil horizons in a soil profile, however, largely depends on the soil depth and drainage condition in addition to topographic situations. Thus while the high level soils without a zone of accumulation of soluble salts (F, G and H types) show proper horizon differentiations between 12 in. and 30 in. depth, similar soils on low levels (A, D and E types) exhibit proper development only between 18 in. and 48 in. (When the soil depths are less than these limits, different horizons are either not distinct or not formed at all and an immature soil type results.) Lastly the soils with zones of accumulation of soluble salts are rarely found with depths of less than 36 in. but may extend up to great depths. These limiting depths of proper profile developments of different soil types are, however, modified to a certain extent, due to the drainage condition of the substratum. (Better drainage extends the limiting depth, whereas inferior drainage tends to shorten it.)

Most of the soil types exhibit horizon differentiations although in some cases, like C and D types, the boundary lines are not so well demarcated, yet there is a perceptible change in the structure in passing down the profile in the latter cases. In the profile descriptions of the soil types, wherever physical differentiations into different horizons have been possible, they have been designated as horizons I, II, III, etc. From foregoing discussions it would be apparent that I is the eluvial or 'A' horizon,* II and III are the illuvial or B_1 and B_2 horizons* in the case of soil types A, B, F and H (A and F types contain only A and B horizons). In the case of C and D types illuviation of different ingredients takes place in different depths, but sharp demarcations are not possible chemically. Finally in E and G types no such distinct chemical eluviation from horizon I into II can be traced, although it is evident that the soluble products of weathering must have been removed from these soils and hence $I=A_1$ and $II=A_2$ horizon in these cases are more appropriate. From the pedogenic point of view these two soils are in a less advanced stage of tropica weathering. Further, from the examination of data of residue insoluble in hydrochloric acid, it is also clear that the existence of C horizon even in the deeper soils is not traceable (up to the depths of analysis at least).

To what extent the development of the first horizon is due to human interference is difficult to gauge at the present moment. The loose and porous nature of A_1 horizon in the case of E and G types are, however, difficult to account from the chemical data at our disposal, unless such an assumption is made. (This zone corresponds with the root zones of cereal crops.) The compaction of the second horizon varies a good deal in the different soil types and is most important from the agricultural point of view. Thus E and F types have compact second horizons at 12 in. and 8 in. respectively which hinder both the root penetration and free percolation of water through this layer. From comparative profile studies it has also been observed that these soils turn alkaline under irrigation. The soil type C which shows hindrance to penetration of water also exhibits similar characteristics. In other cases where the second horizon is permeable penetration of roots is usually deep into the B horizon where the soluble products of soil-weathering usually accumulate. These soils are usually very suitable for perennial irrigation and cane-growing.

In the last group (soils with a zone of accumulation of soluble salts) two further sub-groups may be recognised: (1) soils exhibiting hard and compact A horizon possessing very high percentage of exchange sodium and (2) soils without such inferior structure in the A horizon. Agriculturally these divisions have a profound significance on the growth of plants and the behaviour of soils under irrigation. In practice, however, (2) passes into (1) very imperceptibly with increasing soil depth and change in the drainage condition of the substratum and a sharp boundary line is very difficult to draw between the two by means of chemical analyses. Work is in progress to find out the limiting percentage of sodium saturation at which the soil develops these properties of the A horizon which hinders plant growth.

---

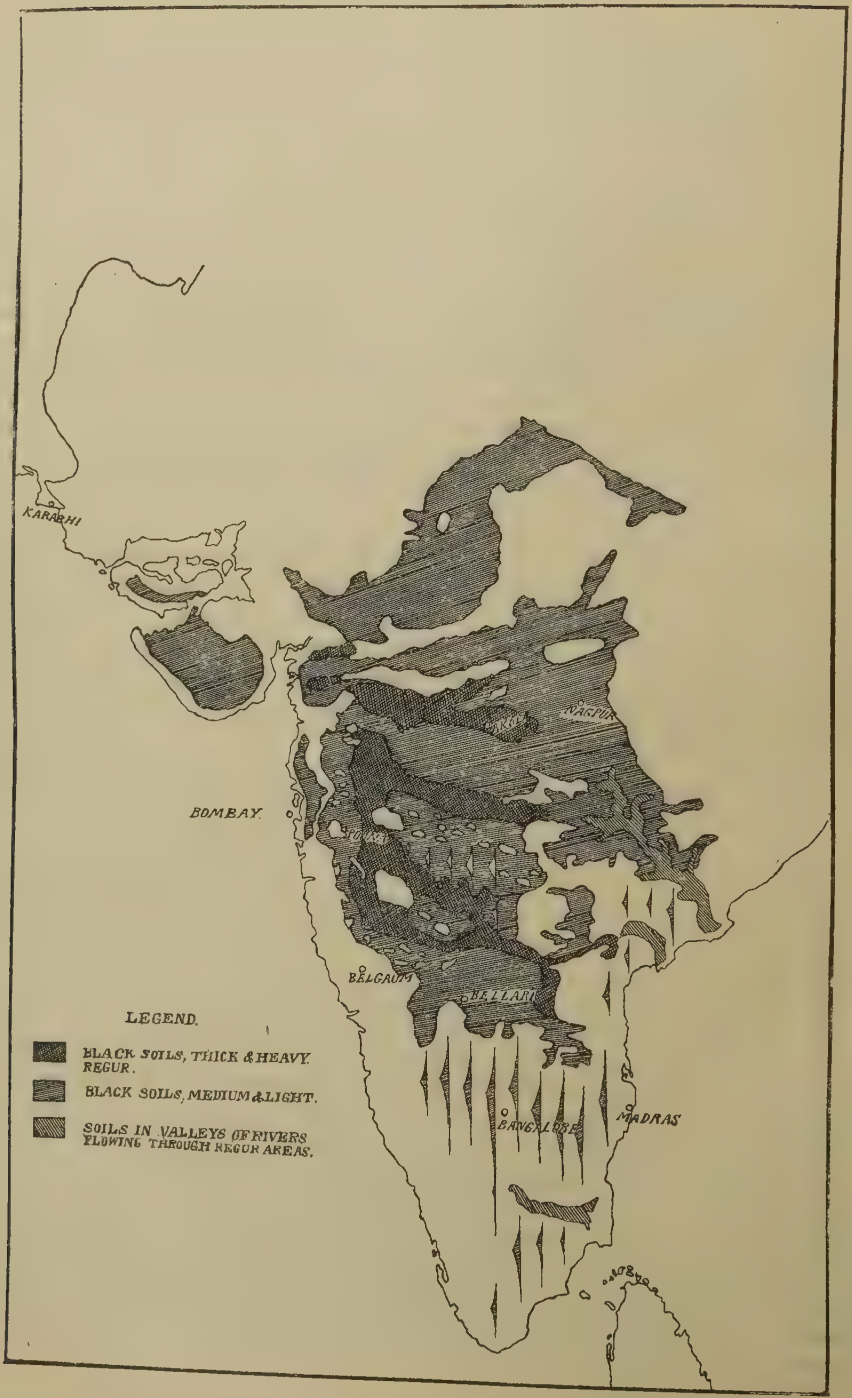
*Refer to 'Glossary' at the end of the paper.

In any comprehensive system of soil classification the compaction of the A horizon is an attribute which should be reckoned with fully, as this will determine the suitability or otherwise of crops. (These soils with pronounced compaction of the A horizon have been provisionally classified under 'degraded' soil types.)

V. POSITION OF THE SOILS IN THE WORLD GROUP OF SOIL CLASSIFICATION

The soils of the Deccan Canals undoubtedly belong to that broad group of Indian soils popularly known as the black cotton soils of India. Although found over various geological formations and under wide ranges of climate, these soils exhibit certain unfailing soil characteristics which have placed them in a distinct soil group. Main peculiarities of these soils are their slaty-black to very dark brown colour and the unusual degree to which they contract on drying. These soils occupy a very important position in the soil studies in India and have long attracted the attention of various soil scientists.

The close similarity of these soils with the tschernosems of Russia has been the subject of discussion in various text-books but no definite conclusion has been arrived at as yet. Glinka [1914] in his book on "The Great Soil Groups of the World" wrote, "It is not possible to identify the Indian regur as equivalent to the Eurasian tschernosem on account of insufficient information concerning its profile. The history of the investigation of this interesting soil is like that of the Russian tschernosem". We again find in the same book—"The structure of the regur, briefly described by Richthofen is the most reliable information we have for forming our opinion on the relationship of the two soils. Richthofen mentions the occurrence of lime concretions beneath the dark coloured surface horizon. He states also that (1) the regions in which the regur occurs are covered with tall grass, (2) it carries no forests, (3) the annual precipitation is less than 48 in. and (4) there is a well-defined dry season and the change from one to the other is rapid". From a study of the available literature, Schokalsky [1933] has been able to prepare a soil map of India (Fig. 8) in which she has subdivided the black cotton soils into three classes ; (1) black soils, thick and heavy ; (2) black soils, medium and light ; (3) soils in valleys of rivers flowing through regur area. Sufficient analytical data are, however, not available in this connection in order to characterise these classes of soils genetically. Later in a publication of Hosking [1935], some valuable information regarding these soils is available. Unfortunately these samples were mostly from the surface soil, and in a few cases where the profile samples have been analysed morphological descriptions of these soils are not supplied. No attempt has been made to follow up the pedogenic processes undergoing in these soils and hence it is not possible to study as to what extent these soils are akin to the tschernosems of Russia beyond the fact that they are highly base-saturated and low in organic matter contents.


KARACHI
BOMBAY
POONA
NAGPUR
BELGAUM
BELLARI
BANGALORE
MADRAS
LEGEND.
BLACK SOILS, THICK & HEAVY REGUR.
BLACK SOILS, MEDIUM & LIGHT.
SOILS IN VALLEYS OF RIVERS FLOWING THROUGH REGUR AREAS.

[After Z. J. Schokalsky

Fig. 8. Soil map of India showing the area under black cotton soils (scale 1 : 15.000,000)

Here we propose to deal with this question more fully from a consideration of the data already presented in a previous section.

(1) The first and foremost question is the colour of the soils. The eight types of soil described in this paper are of varied colours, *e.g.*, deep black, greyish black, brownish black, dark brown, reddish brown and light brown. They may, however, be broadly divided into groups : (*i*) soil colour in which black is the fundamental colour associated with either grey or brown shades, (*ii*) soil colour in which brown forms the major colour with admixtures of black, grey or reddish tinge. The former group of colours is possessed by the tschernosems or black earths of Russia and the soil types A to E resemble them most nearly, whereas in the latter group we have the chestnut or brown earths to which the soil types F, G and H approximate closely.

(2) The organic matter contents of tschernosem soils are usually between 8 and 10 per cent although low figures of 4 and 6 per cent are not uncommon in the case of Northern or Southern tschernosems. The organic matter contents of chestnut earths vary from 3 to 5 per cent, whereas brown earths may contain from 1 to 2 per cent only. From the point of view of organic matter contents therefore the Bombay-Deccan soils are more akin to brown earths than either to chestnut or black earths. The black colour of some of these soils cannot therefore be explained merely by the organic matter contents. The black colour has been either ascribed to a black mineral —titanic magnetite—associated with this type of soil [Annett, 1909] or to a complex organic compound of iron and aluminium [Harrison and Ramaswamy Sivan, 1912]. Robinson [1932], however, explains the black colour as due to the peculiar nature of humification processes proceeding in a neutral or alkaline medium as obtains in a highly base-saturated soil subjected to high summer temperatures. This theory, though affording a satisfactory explanation of the black colour of base-saturated soils in presence of even small amounts of organic matter, fails to give a clue to the uniformly dark colour of some of the very deep soils under semi-arid climatic conditions, where the pedogenic processes are expected to extend only up to 5 or 6 ft. of soil from the surface. Some of the deeper soil profiles are under examination at present, which is likely to shed light in this direction.

(3) The next point under consideration is the characteristics of the soil profiles. Although the soils are occasionally very shallow, the structure profile more closely resembles a tschernosem soil than that of a chestnut earth in possessing a well-defined granular or crumb structure so characteristic of the former. Some thin skeletal soils have some affinity for this latter type as the ultimate structure of these soils are ‘ single-grained ’. The colour profile of a tschernosem soil, however, differs considerably from those of the soil types A to H (excepting the B type) in the fact that the dark coloured layer is not necessarily differentiated into two horizons, *i.e.*, an upper A_1 and a lower A_2, the latter having a lighter colour and lower organic content. The morphology of the B type profile closely agrees with that of an ordinary tschernosem.

(4) The zone of accumulation of calcium carbonate is a profile characteristic of both the tschernosem and chestnut earths (in fact the 'pedocal' group of soils of Marbut [1928] is based on this property). In the present instance, accumulation zones are shown in the case of the soil types B, C and D only, although pronounced eluviations are shown by H, F, G and A types also. If the depth of the soil is sufficient the zones of accumulations of calcium carbonate are usually followed by accumulation zones of total salts. In a true tschernosem, however, soluble salts are completely leached out and it is only in the case of chestnut or brown earths that such accumulations of soluble salts are observed. Another special point about these soils is that they effervesce on the surface on treatment with dilute acid (except H type) whereas a tschernosem or chestnut earth rarely does so unless they are derived from a parent material rich in calcium carbonate. From this point of view all the soils (except H type) belong to the carbonate soil group. It reflects the comparatively recent origin of these soils as well as the greater aridity of the climate than that obtaining in the Russian tschernosem or chestnut earth zones.

(5) The occurrence of *krotwinas* or the passage ways of burrowing animals in the soil profile has been described as an unfailing sign of a true tschernosem soil. They appear in the soil profile as oval or irregularly formed spots which can be seen in the humus horizon only when they are filled up with the lighter coloured parent rock. *Krotwinas*, however, have never been observed in these soils. This may be due to the extreme desiccation of these soils in summer, when coupled with extreme heat the soil becomes quite unsuitable for earth worms and other burrowing animals.

(6) Another peculiarity of tschernosem soils and chestnut earths is their complete absence of eluviation of clay in the profile. This is, however, not strictly true for all the soils of the Bombay-Deccan. Thus, considerable eluviation of the clay complex may be noticed in the profiles of B and C types and gentler eluviations in the A, F and H types. This fact can be partially attributed to the heavy downpours that occur in the later periods of the monsoon which are absent in Russia, where the heaviest falls are by way of winter snows which do not cause any rapid circulation of water in the entire soil mass.

(7) It is maintained that in tschernosem soils the alumino-silicate complex attains its highest stability, due to the high calcium base status of the colloid, combined with the protective influences of neutral humus. Hence the eluviations of either silica or sesquioxides are never encountered in these soils. In the present instance, however, evidences of slight eluviation of silica, alumina and ferric oxide are noticed in certain soil types. Thus the soil types A, B, C, D and F exhibit a leaching tendency for silica; A, C, D and H for alumina and A, B and C for ferric oxide. In spite of the high calcium status of these soils it is apparent that destructive processes have already set in in certain types liberating silica and sesquioxides and leading to the partial removal of these ingredients

from the seat of reaction. The causes of this breakdown of the silicate complex and the mobilisation of the products may be attributed to the following factors :—(*i*) The soils are subjected to very high temperatures in summer which is not the case in the tschernosem soils of Russia. (*ii*) Rainfall, though usually low comes occasionally with a heavy downpour, which helps to mobilise the products of chemical weathering downwards. (*iii*) Alkalinity often attains quite high values (pH 8·5 to 9·0), due to incomplete leaching of sodium salts from the profile, which aids the solubility of these products considerably. This is not the case in a true tschernosem where soluble salts are completely leached out and the pH rarely exceeds 7·5 to 8·0. (*iv*) Due to extreme heat, the decomposition of organic matter takes place very rapidly, thus producing a large quantity of carbonic acid in the soil which helps to dissolve the weathered products, especially the sesquioxides (p. 641). The eluviation of ferric oxide probably takes place as ferrous bicarbonate in presence of excess of carbon dioxide in partially anaerobic conditions. The brown to reddish brown colour of certain soil profiles (*i.e.*, F, G and H types) indicates clearly the presence of free sesquioxides in the soil which must have been formed due to the destruction of the complex by the combined effect of high temperature and extreme desiccation in summer, when the components liberated, *viz.*, silicic acid and sesquioxides undergo irreversible changes.

Thus the position of these soils may be summed up as under :—

The soils described in this paper broadly come under the tschernosem soil group due to the fact that they are all highly base-saturated (mainly with calcium) and normally possess well-defined granular or crumb structure, although some of the soils possess a brown colour like that of chestnut earths. Some of these soils, however, grade towards solonetz-like soil (alkali soil with structure) when the percentage sodium in the exchange complex increases considerably on the surface soil, due to either topographic situation or impedence of the underlying parent material. Fundamental differences are however (*i*) low humus contents of these soils, (*ii*) calcareous nature of the surface soil, (*iii*) absence of zones of accumulation of calcium carbonate in certain soils, due to shallower depths and presence of a zone of accumulation of soluble salts in addition to calcium carbonate in deeper profiles, (*iv*) influences of a tropical climate are felt in the eluviation of clay, silica, alumina and ferric oxide in certain profiles. From all these pedogenic considerations it would be safe to class these soils tentatively in a separate group altogether and term them as ‘ immature tropical tschernosems ’, immature because the leaching processes have not proceeded as far as in the proper tschernosems, and tropical because of the evidences of the breakdown of the silicate complex in certain soils.

Until further evidences are forthcoming regarding the nature of the soil-forming processes under definitely higher rainfall conditions, it would not be possible to generalise on the genetic nature of this very important broad group of Indian soils.

VI. A SCHEME OF SOIL CLASSIFICATION FOR THE DECCAN SOILS

As a result of the present study, a practical scheme of soil classification has been evolved, which takes into account the profile characteristics as its fundamental basis, yet capable of expansion to fit in newer soil types.

Broadly speaking, the soils of the Deccan Canals can be divided into two major groups according to the operation of two sets of soil-forming processes.

Group I. Soils developed under conditions of restricted drainage

These soils generally exhibit on the surface horizon definite lumpy or clod-like structure (which breaks up ultimately into fine crumbs, unless the soil is saturated with sodium base) with zones of accumulation of soluble salts in the lower horizons. Soils are greyish black to deep black in colour. These are again divided into : (*a*) soils possessing sharply differentiated horizons by colour, (*b*) soils with no differentiation in colour. Both (*a*) and (*b*) can be further sub-divided into (*i*) a normal soil having low exchange sodium in the surface horizon, (*ii*) a degraded type possessing a high percentage of exchange sodium in the surface horizon with a compact structure. Thus—

I (*a*) (*i*)—B type ;

I (*a*) (*ii*)—degraded B type ;

I (*b*) (*i*) —C type ;

I (*b*) (*ii*)—degraded C type

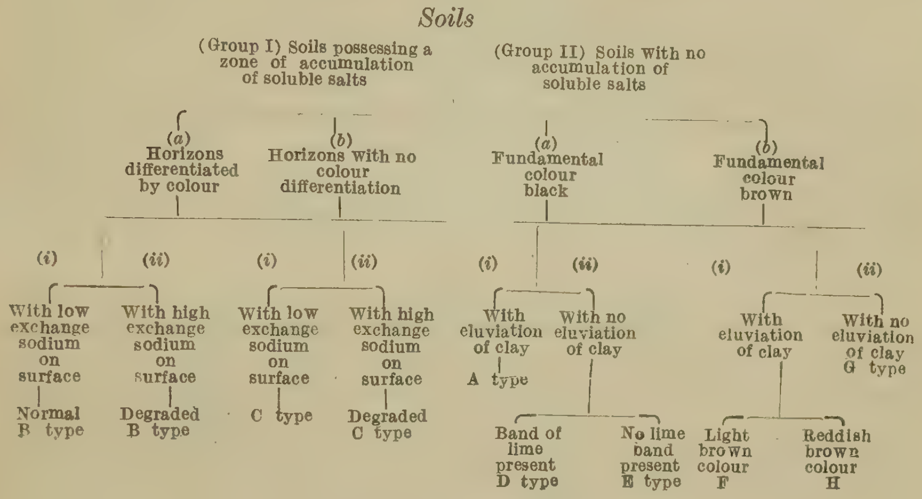
Group II. Soils developed under conditions of free drainage

All the soils under this head are without any heavy structure on the surface (usually crumby or loose and granular) and are of varying colour and consistency. They may be black, greyish black, brown, deep brown to reddish brown in colour and the texture may vary from loam to clay soils. But from the point of view of colour these soils may be divided into : (*a*) soils possessing black as fundamental colour, (*b*) soils possessing brown as fundamental colour. The distinct sub-divisions can be recognised in both the groups resulting from mechanical eluviation of the clay complex : (*i*) soil profile exhibiting definite eluviation of clay, and (*ii*) soil profile in which no such eluviation of clay has taken place. Thus we have II (*a*) (*i*)—A type ; II (*a*) (*ii*)—E and D types ; II (*b*) (*i*)—H and F types ; II (*b*) (*ii*)—G type. Further sub-division of II (*a*) (*ii*) is simple as D type possesses a thick band of lime below the soil horizon whereas E type does not possess any such lime layer. F and H types are characterised by colour at the first instance (*e.g.* F type is light brown whereas H type is reddish brown).

For final confirmation of the soil types, more detailed analysis as outlined in the paper may be found necessary.

This soil classification is shown below :—

A classification of Deccan Canal soils


Soils
(Group I) Soils possessing a zone of accumulation of soluble salts
(Group II) Soils with no accumulation of soluble salts
(a) Horizons differentiated by colour
(b) Horizons with no colour differentiation
(a) Fundamental colour black
(b) Fundamental colour brown
(i)
(ii)
(i)
(ii)
(i)
(ii)
(i)
(ii)
With low exchange sodium on surface
With high exchange sodium on surface
With low exchange sodium on surface
With high exchange sodium on surface
With eluviation of clay
With no eluviation of clay
With eluviation of clay
With no eluviation of clay G type
Normal B type
Degraded B type
C type
Degraded C type
A type
Band of lime present D type
No lime band present E type
Light brown colour F
Reddish brown colour H

VII. Summary and conclusions

From an examination of a large number of profiles distributed over fairly representative parts of the Nira Right Bank and Pravara Canals, eight soil types have been traced, whose complete analysis has been presented in this paper. Salient features of this investigation are summarised below :—

(1) All the normal soils of the tract possess a well-developed crumb structure and exhibit two to three horizons which are differentiated more or less sharply by colour, structure, texture or by the presence or absence of concretions. These horizons have been named as A_1, B_1, B_2 or A_1, A_2, according to the presence or absence of illuviation of material in the lower horizons. The first horizon is always loose and granular, whereas the second horizon is in some cases very compact and interferes with proper root development and drainage.

(2) Degradation of soil types occur with impeded drainage or nearness of subsoil water when the profile develops a hard and compact A horizon which comes in the way of cultivation and irrigation. In very shallow soils, horizon development is rarely observed and an immature or skeletal soil type results. Investigations on such soils are in progress.

(3) Colour of the soils seems to be more related with the moisture relationship of soils than with the actual amounts of organic matter present. Fundamentally black-coloured soils are usually found on low-lying situations, where the soils remain moist over a considerable part of the year when compared with soils on a high level where the colour is usually brown. This brown colour also indicates some breakdown of the clay complex, due to high temperatures and extreme desiccation in the summer.

(4) Evidences of tropical weathering have been found in certain soils where eluviation of clay, silica and sesquioxides has taken place. This has been attributed to the breakdown of the clay complex due to high temperatures and the subsequent mobilization of the products by the torrential showers to which they are subjected during the later part of the monsoon.

(5) High base status together with the well-defined crumb structure of these soils places them undoubtedly in the tschernosem soils group although the black colour is not universal, due to tropical nature of soil-weathering in some cases. Calcareous character of the surface soil-together with zones of accumulation of soluble salts in the deeper profiles point out their immature nature and hence these soils can be provisionally placed under a new group 'immature tropical tschernosem'.

(6) The average annual rainfall over the tract is less than 25 in. and the mean annual temperature about 76°F. (24·4°C.). The distribution of the rainfall induces a steppe type of vegetation, whereas wide fluctuations in temperature and moisture conditions of the soil cause rapid weathering, giving rise to high clay formation together with high base-exchange capacities of the soils. Soil climate is, however, greatly modified by topography and the soil forming processes differ widely under different elements of relief. At the same time although the geological formation, *viz.*, the Deccan traps from which the soils originate is the same throughout and has a fairly uniform petrological composition, there is reason to believe that local variations in the composition of the rock may lead to significant differences in the mineral ingredients of the soil, important from the view either of its fertility or its physico-chemical characteristics. All these factors have been held responsible for the wide differences in the soil types existing in this tract.

Acknowledgments

The authors wish to express their indebtedness to the Deputy Director of Agriculture, S. C. D., Poona, and the members of his canal staff, for ungrudging assistance in touring and field work throughout the period of survey.

REFERENCES

Annett, H. E. (1910). *Mem. Dept. Agric. Ind.* (*Chem. Ser.*) **1**, No. 9

Bal, D. V. (1925). *J. Agric. Sci.* **15**, 454-59

Basu, J. K. (1931). *J. Agric. Sci.* **21**, 484-92

Crowther, E. M. (1930). *Proc. Roy. Soc.* **107**, 3

Crowther, E. M. and Basu, J. K. (1931). *J. Agric. Sci.* **21**, 710

Davis, R. O. E. (1927). *U. S. A. Dept. Agric. Circular No.* **423** (*Washington D. C.*)

Glinka, K. D. (1914). "The Great Soil Groups of the World and their Development" translated from the German by C. F. Marbut, 1927. Edward Brothers, Inc., Michigan, pp. 78-79

Harrison, W. H. and Ramaswamy Sivan, M. R. (1912). *Mem. Dept. Agric. Ind.* (*Chem. Ser.*) **2**, No. 5

Hosking, J. S. (1935). *Waite Agric. Res. Inst. ' Trans. Roy Soc. of Australia '* **59**

Inglis, C. C. and Gokhale, V. K. (1929). *Bombay P. W. D. Tech. Paper No.* **13**, 1-13

Joshi, K. V. (1930). *Bombay Dept. Agric. Bull.* **165**, 9 and 44

Marbut, C. F. (1928). *Proc. 1st Int. Congr. Soil Sci.* **4**, 1-31

Mollison, J. (1900). " A Text-book of Indian Agriculture " Vol. **I**, pp. 34-38

Robinson, G. W. (1932). " Soils, their Origin, Constitution and Classification ", pp. 73 and 225. London : Thomas Murby and Co.

Russell, E. J. (1932). " Soil Conditions and Plant Growth " (Sixth Edition), pp. 560, 570. Longmans, Green and Co.

Sahasrabuddhe, D. L. (1929). *Bombay Dept. Agric. Bull.* **160**, 1-84

Schokalsky, Z. J. (1933). " The Natural Conditions of Soil Formation in India " pp. 106-107, 122. Dokuchaiev Inst. Soil Sci.

Sigmond, A. A. J. De (1927, 1). " Hungarian Alkali Soils and Methods of their Reclamation ", pp. 22-25. Univ. of Calif. Printing Office.

———————— (1927, 2). *Proc. 1st Internat. Cong. Soil Sci.* **1**

Steenkamp, J. L. (1934). *Imp. Bur. Soil. Sci. Recent Developments in Soil Analysis No.* **5**, 13-15 & 3-5

Wadia, D. N. (1926). " Geology of India for Students ", pp. 192-200. London : Macmillan & Co.

GLOSSARY

Soil-profile.—The complete succession of soil-layers or ' horizons ' down to the undifferentiated parent material.

Horizons.—Definite soil layers differentiated from each other by a series of soil-forming processes, due to water movements within the soil, whereby the products of weathering are differentially separated.

Eluvial horizon or ' A ' horizon.—Horizon from which products of weathering are removed. Process of such removal or impoverishment is termed ' eluviation '.

Illuvial horizon or ' B ' horizon.—Horizon which is enriched by additions from without. This process of enrichment or accumulation is called ' illuviation '. Sub-divisions of the ' A ' and ' B ' horizons are denoted by A_1, A_2, A_3, etc., or B_1, B_2, B_3, etc., according to the characteristic impoverishment or enrichment of constituents, like clay, humus, iron, silica, etc.

' C ' horizon.—Usually the parent material from which the soil has been derived and which underlies the soil.

Genetic classification.—System of classification evolved by the Russian school of soil scientists in which the soil profile is taken as the unit of study. It is assumed that the complete expression of the pedogenic processes, acting on a given parent material, is found in the soil profile.

A STUDY OF FACTORS INFLUENCING THE EXTRACTION OF JUICE FROM SUGARCANE

BY

RAMJI NARAIN, PH.D., D.SC.

AND

AZMAT SINGH, L.AG.

Department of Agriculture, Punjab, Lyallpur

THE two main factors, which determine the superiority or inferiority of any particular variety of sugarcane with respect to another, are the quality and quantity of the juice obtained from it. A variety can be regarded as suitable only when it yields a sufficient amount of juice of good quality. For all practical purposes different varieties can be graded on the basis of this criterion. While quality is mostly an inherent characteristic of any particular variety, the quantity of juice that can be obtained from it may also be influenced considerably by external conditions which prevail during crushing. The effect of these may sometimes be so great that when the analytical data are expressed as percentage on cane, the errors due to crushing may modify the final figures of the various constituents estimated to such an extent that qualitative differences existing in different varieties or in the same variety when grown under different cultural or manurial treatments may be considerably masked. It therefore becomes a matter of great importance to the cane investigator to study carefully all those external conditions which may exert an influence on the amount of juice obtained from the same variety of cane.

Some preliminary observations on this important problem were carried out at Lyallpur during the sugarcane season of 1935-36, and a reference to the results then obtained was made in the paper entitled " Sampling of Sugarcane for Chemical Analysis, Part I " [Ramji Narain and Singh, 1937]. It was observed that unless the conditions under which the cane is crushed are exactly specified and adhered to, it is not possible to obtain a reliably comparable figure for juice percentage. During the sugarcane season (*i.e.*, 1936-37) this problem was examined in greater detail at Gurdaspur and the results obtained are presented in the following pages.

The amount of juice obtained from any variety of cane, in addition to the nature of the cane crushed, as shown by its hardness, brittleness and the fibre-content—factors which are more important under factory conditions—mostly depends upon the following three factors :—

1. Setting of the mill.
2. Speed of the working bullocks.
3. The amount of feed.

As in simple agricultural experiments relating to the study of single factors, the effects of any one of the above-mentioned three factors upon the percentage extraction of juice could have been studied by taking up each one separately. In the present case, however, these factors are closely interrelated, and hence their combined effects are as important as the effect of any single factor. A study on the lines of simple agricultural experiments suffers from the serious drawback that it does not give any idea of the relative efficiency of a set of different types of factors operating simultaneously during crushing, or even of the effect of any one in relation to the other. It was, therefore, considered desirable to plan the experiment on the lines of a factorial design in agricultural field trials. This procedure rendered it possible to combine every one of a set of differential treatments with each one of the other sets and thus to impart to each set the same precision as would have been possible if the entire experiment had been devoted to a study of that alone. Such a design also supplies information with equal precision on differential responses of the various factors studied. The large number of degrees of freedom available provides a more precise estimate of the residual error.

The following levels of each of the above-mentioned three factors were studied in all their combinations :—

$$\begin{matrix} (a) & & (b) & & (c) \\ \begin{Bmatrix} \mathrm{T}_1 \\ \\ \mathrm{T}_2 \end{Bmatrix} & \times & \begin{Bmatrix} \mathrm{E} \\ \\ \mathrm{F} \end{Bmatrix} & \times & \begin{Bmatrix} \mathrm{L} \\ \mathrm{M} \\ \mathrm{H} \end{Bmatrix} \end{matrix}$$

where (*a*) *Setting of the mill* is denoted by

(*i*) T_1 = tight setting and
(*ii*) T_2 = extra tight setting

(*b*) *Speed of working bullocks* is denoted by

(*i*) E = easy pace, and
(*ii*) F = fast pace ;

(*c*) *Feeding of the mill* is denoted by

(*i*) L = light feed,
(*ii*) M = medium feed, and
(*iii*) H = heavy feed,

giving the following twelve treatment combinations :—

1. T_1 E L
2. T_1 E M
3. T_1 E H
4. T_1 F L
5. T_1 F M
6. T_1 F H
7. T_2 E L
8. T_2 E M
9. T_2 E H
10. T_2 F L
11. T_2 F M
12. T_2 F H

In all, forty-eight samples of one variety were first picked at random from the same heap of cane, selected in the manner described later. These samples were then divided at random into four groups of twelve samples each. Each of these twelve samples was thus replicated four times, the allotment of the corresponding number of samples in each group being precisely analogous to a random distribution of twelve treatments in four randomised blocks in an agricultural experiment.

Since a set of conditions which may be considered suitable for the extraction of juice from a thin type of cane may not be equally good for other types of canes differing in thickness, it was decided to include in this investigation canes of different varieties with different thicknesses. The data from each population have therefore been examined separately.

DEFINITIONS

A number of terms used in this paper are conventional and require explanation. For instance, the different levels of three factors of variation under study may convey different meaning to different workers. Similarly a variety of sugarcane which is considered thick in one locality may be regarded as only of medium thickness at another place, and a fast speed of short statured bullocks may be confused with an easy pace of large-sized animals. Therefore, for the sake of clarity the exact significance attaching to these terms is explained below in some detail.

1. Setting of the mill.—The mill used for the crushing of cane for these experiments was a three-rollered Nahan mill.* The canes were crushed under two different degrees of setting of the mill rollers called ‘ tight ’ and ‘ extra tight ’. Since the rollers in these mills are very rarely uniform in diameter, the two do not touch each other over their entire length, a thin slit being left at certain points of contact. This degree of setting which is technically known as metal to metal setting, has been designated as ‘ tight setting ’ in this paper. The rollers were further tightened as far as possible consistent with the safety of the mill and this setting has been termed ‘ extra tight ’.

2. Speed of rollers.—The speed with which the mill works depends upon the pace at which the bullocks move, but the latter, as explained already is liable to vary with the types of bullocks available. The number of revolutions of the largest roller per minute is a more reliable standard which could be duplicated whenever required. A few minutes after starting the mill the bullocks settle down to a more or less uniform pace, which, with a little care can, without introducing any serious error, be increased or decreased in accordance with the number of revolutions required. A speed corresponding to three revolutions of the roller per minute has been designated as ‘ easy ’ and that from five to six as 'fast'. The easy speed corresponds more or less to a normal or convenient pace of bullocks moving with their eyes covered with blind goggles. To attain the fast speed, the bullocks had to be specially driven.

---

* Diameter and height of the three rollers of the mill used were 8·3 in. and 8·7 in., 8·3 in. and 8·7 in., and 6·7 in. and 7·1 in. respectively.

3. *Feeding of the mill.*—The number of canes passing through the mill at one time was kept at three levels, called 'light', 'medium' and 'heavy'. In the case of a thin cane like Katha, these three levels consisted of 5, 8, and 12 canes respectively, and for the other types of canes studied of 2, 4, and 6 canes. During normal crushing, about 7 or 8 canes of the thin type and 4 of the medium type are usually fed. Therefore, we fixed our level of medium feed at these figures, varying the number slightly for light and heavy feeds on either side.

4. *Description of the material used.*—In order to evaluate the combined effect of the three factors under investigation on the amount of juice extracted from cane, it is highly desirable that the individuals composing the population should be as uniform as possible. Common experience, however, shows that although the crop standing in a field of sugarcane may appear to be fairly uniform, it is found invariably, after harvesting, to consist of canes of many different sizes which may differ widely in their juice percentage. Consequently it was considered necessary to eliminate as far as possible any variation due to this cause by a previous selection of medium types of canes of apparently as uniform a description as possible, using for this purpose the same heap of harvested canes from the field. The question may, however, arise as to how far the application of the results obtained from this artificially constructed population to other samples which include all types of canes of various descriptions, is justifiable. In view of this objection, perhaps it would have been better had the samples been drawn from the original population composed of individuals differing in size and shape. But in this case, owing to larger sampling variation the experimental error would have been much greater than that which has now been obtained, with the result that the effects of the various factors could not have been demonstrated so prominently as has been possible, without either unduly increasing the size of the sample or by providing a very large number of repeats. However, other considerations, such as the desirability of finishing the entire work in a single day, using a reasonable number of bullocks for crushing, etc., make it very difficult to adopt in actual practice either of these two alternatives. In view of the fact that differences in the juice percentage of samples prepared in the manner described above, due to different sets of conditions of extraction, are not likely to be very widely different from those obtained under a similar set of conditions but from samples collected by randomisation as is done in an ordinary routine analysis, the conclusions arrived at from a consideration of the present data may well apply to routine samples without introducing any serious error.

The varieties of canes used for the purpose of this investigation were Katha (a thin type) and Co 285, Co 213 and Co 312 which belong to the medium type of canes.

The following statement shows the gramme-foot weights (the mean weight in grammes of one foot length) and the corresponding thickness of the different samples used in this investigation.

Serial No.	Variety of cane	Gramme-foot weights of canes	Thickness (average diameter in cm.)
1	Katha	30·9±0·54	1·14
2	Co 285	82·6±2·42	1·72
3	Co 213	96·8±1·79	1·90
4	Co 312	109·8±2·60	2·03

EXPERIMENTAL DATA

The figures for juice percentage from the above varieties of cane under different conditions of extraction are given in Table I. For the sake of convenience and comprehension the figures from all the four repeats pertaining to any treatment have been arranged systematically.

TABLE I

Percentage of juice obtained from different varieties of cane under different conditions of extraction

Serial No.	Repeats	Conditions of extraction of juice			Per cent juice			
					Varieties			
		Setting of mill	Speed of working bullocks	Feeding of mill	Katha	Co 285	Co 213	Co 312
1	I	T_1	E	Light .	58·4	57·5	65·7	64·2
2	I	T_1	E	Medium .	58·6	60·9	66·9	64·7
3	I	T_1	E	Heavy .	57·9	58·7	64·9	64·9
4	I	T_1	F	Light .	57·0	56·0	63·5	62·2
5	I	T_1	F	Medium .	57·1	56·7	65·4	64·1
6	I	T_1	F	Heavy .	56·6	57·8	62·6	62·9

TABLE I—*contd.*

Serial No.	Repeats	Conditions of extraction of juice			Per cent juice			
					Varieties			
		Setting of mill	Speed of working bullocks	Feeding of mill	Katha	Co 285	Co 213	Co 312
7	I	T_2	E	Light	59·0	59·9	66·9	65·0
8	I	T_2	E	Medium	60·9	63·3	66·4	66·1
9	I	T_2	E	Heavy	58·6	63·2	64·7	62·9
10	I	T_2	F	Light	59·3	58·8	66·3	63·0
11	I	T_2	F	Medium	58·9	61·8	65·4	63·1
12	I	T_2	F	Heavy	59·1	59·0	63·9	60·4
13	II	T_1	E	Light	57·7	57·9	66·5	64·1
14	II	T_1	E	Medium	58·1	59·0	67·1	64·5
15	II	T_1	E	Heavy	58·6	58·8	65·6	65·4
16	II	T_1	F	Light	56·6	56·5	64·8	64·9
17	II	T_1	F	Medium	56·2	57·5	63·6	64·1
18	II	T_1	F	Heavy	57·0	57·2	62·9	63·9
19	II	T_2	E	Light	58·5	60·4	66·7	64·3
20	II	T_2	E	Medium	58·6	62·9	66·4	64·3
21	II	T_2	E	Heavy	60·6	61·5	65·0	62·9
22	II	T_2	F	Light	58·8	59·7	65·3	64·5
23	II	T_2	F	Medium	58·4	60·0	66·2	63·3
24	II	T_2	F	Heavy	57·9	58·4	62·0	61·3
25	III	T_1	E	Light	57·2	57·5	66·6	64·8
26	III	T_1	E	Medium	58·0	58·7	67·1	66·2
27	III	T_1	E	Heavy	57·7	58·0	66·0	64·5
28	III	T_1	F	Light	57·2	56·9	64·7	64·0
29	III	T_1	F	Medium	56·8	58·3	64·8	63·6
30	III	T_1	F	Heavy	57·7	57·3	62·3	63·0

TABLE I—*concld.*

Serial No.	Repeats	Conditions of extraction of juice			Per cent juice			
					Verieties			
		Setting of mill	Speed of working bullocks	Feeding of mill	Katha	Co 285	Co 213	Co 312
31	III	T_2	E	Light	58·2	60·2	67·5	65·2
32	III	T_2	E	Medium	60·1	62·2	67·2	64·4
33	III	T_2	E	Heavy	60·1	60·8	65·0	64·3
34	III	T_2	F	Light	59·0	60·8	65·0	64·0
35	III	T_2	F	Medium	58·9	60·5	65·0	63·2
36	III	T_2	F	Heavy	58·3	57·1	62·9	63·3
37	IV	T_1	E	Light	58·3	57·5	65·5	65·7
38	IV	T_1	E	Medium	58·8	59·2	66·7	64·8
39	IV	T_1	E	Heavy	58·4	58·6	65·5	63·9
40	IV	T_1	F	Light	55·2	56·6	63·3	63·9
41	IV	T_1	F	Medium	57·7	58·0	65·6	63·7
42	IV	T_1	F	Heavy	56·1	55·7	63·5	63·5
43	IV	T_2	E	Light	59·5	60·6	66·5	65·9
44	IV	T_2	E	Medium	58·8	62·6	66·7	64·8
45	IV	T_2	E	Heavy	58·4	60·7	64·0	63·5
46	IV	T_2	F	Light	56·8	59·7	65·2	62·2
47	IV	T_2	F	Medium	59·4	60·5	64·7	63·6
48	IV	T_2	F	Heavy	58·1	58·2	60·6	60·8

STATISTICAL ANALYSIS AND DISCUSSION OF RESULTS

The analyses of variance of the figures of juice percentage obtained for different varieties are shown in Table II.

TABLE II

Analyses of variance of percentage juice obtained from different samples examined

Factor of variation	Degree of freedom	Mean square	Ratio of variances
Co 285			
Parallels	3	0·41	..
Setting	1	92·97	200·35**
Speed	1	34·68	74·74**
Feed—2 vs. 6	1	0·63	1·36
Feed—4 vs. 2+6	1	21·19	45·67**
Speed × Feed—2 vs. 6	1	5·36	11·55**
Speed × Feed—4 vs. 2+6	1	0·11	0·24
Setting × Feed—2 vs. 6	1	1·49	3·21
Setting × Feed—4 vs. 2+6	1	1·53	3·30
Setting × Speed	1	0·96	2·07
Setting × Speed × Feed—2 vs. 6	1	2·94	6·34*
Setting × Speed × Feed—4 vs. 2+6	1	0·03	0·06
Residual	33	0·464	..
Total	47	..	..
Co 213			
Parallels	3	0·61	..
Setting	1	0·41	0·92
Speed	1	47·20	106·08**
Feed—2 vs. 4	1	0·85	1·91
Feed—6 vs. 2+4	1	40·56	91·14**
Speed × Feed—2 vs. 4	1	0·00	0·00
Speed × Feed—6 vs. 2+4	1	1·61	3·62
Setting × Feed—2 vs. 4	1	2·00	4·49*
Seeting × Feed—6 vs. 2+4	1	4·17	9·37**
Setting × Speed	1	0·91	2·05
Setting × Speed × Feed—2 vs. 4	1	0·02	0·04
Setting × Speed × Feed—6 vs. 2+4	1	0·06	0·13
Residual	33	0·445	..
Total	47	..	..

** Significant at one per cent

* Significant at five per cent

TABLE II—*contd.*

Factor of variation	Degree of freedom	Mean square	Ratio of variances
Katha			
Parallels	3	0·55	..
Setting	1	25·96	46·91**
Speed	1	12·91	22·97**
Feed—8 vs. 5+12	1	1·71	3·04
Feed—5 vs. 12	1	0·61	1·09
Speed × Feed—8 vs. 5+12	1	0·01	0·02
Speed × Feed—5 vs. 12	1	0·21	0·37
Setting × Feed—8 vs. 5+12	1	0·08	0·14
Setting × Feed—5 vs. 12	1	0·01	0·02
Setting × Speed	1	1·37	2·44
Setting × Speed × Feed—8 vs. 5+12	1	0·01	0·02
Setting × Speed × Feed—5 vs. 12	1	0·36	0·64
Residual	33	0·562	..
Total	47	..	..
Co 312			
Parallels	3	0·70	..
Setting	1	4·81	7·87**
Speed	1	25·23	41·29**
Feed—2 vs. 4	1	0·01	0·02
Feed—6 vs. 2+4	1	11·76	19·25**
Speed × Feed—2 vs. 4	1	0·01	0·02
Speed × Feed—6 vs. 2+4	1	0·24	0·39
Setting × Feed—2 vs. 4	1	0·32	0·52
Setting × Feed—6 vs. 2+4	1	5·32	8·71**
Setting × Speed	1	1·02	1·67
Setting × Speed × Feed—2 vs. 4	1	0·05	0·08
Setting × Speed × Feed—6 vs. 2+4	1	0·00	0·00
Residual	33	0·611	..
Total	47	..	..

** Significant at one per cent

In order to obtain complete information on all main effects and differential responses, the eleven degrees of freedom corresponding to the treatments were split up into their unitary elements. In this way it was possible to compare for each variety any one particular level of feed with the other two. In the case of all the varieties, however, the same level of feed was not always used as a standard for comparison with the remaining two. The feed selected was the one which, when compared with the remaining two, showed the widest differences in juice percentage. For instance, in the case of Katha medium feed was compared with light and heavy feeds, while in the case of Co 312 the heavy feed was compared with light and medium feeds. Any other level of feed could have similarly been compared. The latter two feeds, in each case, were also compared with each other. In this way it was possible to see, at a glance, all significant effects due to different levels of the primary factors, individually and in combination with other factors. One more point in connection with the above analyses deserves special mention. As already indicated, the population, from which the forty-eight samples were drawn, was selected to include the medium canes of as similar a description as possible. This reduced the sampling variations to a minimum, with the result that the residual error was quite small in all cases. Further, it was found that the division of the samples into groups did not serve any useful purpose, since this neither increased the precision of the experiment nor in any way modified the conclusions arrived at otherwise. It is thus clear that for all practical purposes there were no differences in parallel samples. Therefore, from the point of view of the present investigation the construction of the population by a previous selection was amply justified.

The ratio of variances are given in the last column of this table. All items significant at a level of one per cent probability are marked with two asterisks and those at five per cent with one. It will be seen that with the exception of only two cases, *viz.*, feeding of the mill in the case of Katha and setting of the mill in Co 213, all the main effects were highly significant. Feeding of the mill, whether in combination with the speed of the working bullocks or setting, seems to exercise a much greater influence on the amount of juice extracted than any combination of speed and setting, the effect of which was throughout insignificant. This shows that of the three factors studied feed is the most important.*

In order to appreciate further, the full implications of the different factors operating during crushing, summary tables (Tables III-V) showing the mean percentage of juice obtained during different conditions and differential responses due to various interacting factors, etc., have been constructed, and the appropriate standard errors given. The data presented in each of these tables are discussed below.

Table III gives the mean values of the percentage juice obtained under different treatments.

---

* This conclusion is also borne out from the data relating to Katha at Rawalpindi and Co 285 at Lyallpur presented and discussed briefly in the appendix.

TABLE III

Mean values of percentage juice obtained under different treatments neglecting the effect of parallel estimations

(*Average of 4 determinations*)

		Light	Medium	Heavy	Mean	Light	Medium	Heavy	Mean
		Co 285				*Katha*			
T$_1$	E	57·60	59·25	58·52	58·46	57·90	58·38	58·15	58·14
	F	56·50	57·62	57·00	57·04	56·50	56·95	56·85	56·77
T$_2$	E	60·28	62·75	61·55	61·53	58·80	59·60	59·43	59·28
	F	59·75	60·70	58·17	59·54	58·48	58·90	58·35	58·58
Standard errors		±0·341		±0·197		±0·375		±0·217	
		Co 213				*Co 312*			
T$_1$	E	66·08	66·95	65·50	66·18	64·70	65·05	64·68	64·81
	F	64·07	64·85	62·82	63·91	63·75	63·87	63·32	63·65
T$_2$	E	66·90	66·68	64·67	66·08	65·10	64·90	63·40	64·47
	F	65.45	65·32	62·35	64·37	63·42	63·30	61·45	62·72
Standard errors		±0·333		±0·192		±0·391		±0·226	

It will be seen that, since the mean value of percentage juice obtained under different conditions differs with different varieties, the data from each sample have been dealt with separately.

The main effects in the case of different samples examined are shown quantitatively in Table IV.

TABLE IV

Effects of main treatments on percentage extraction of juice in different varieties

Feeding of the mill	Speed		Setting		Mean	Increase	Speed		Setting		Mean	Increase
	E	F	T_1	T_2			E	F	T_1	T_2		
	Co 285 ±0·241						Katha ±0·265					
Light	58·94	58·13	57·05	60·02	58·54†	...	58·35	57·49	57·20	58·64	57·92†	...
Medium	61·00	59·16	58·44	61·72	60·08†	+1·54††	58·99	57·93	57·66	59·25	58·46†	+0·54††
Heavy	60·04	57·58	57·76	59·86	58·81†	—1·27††	58·79	57·60	57·50	58·89	58·19†	—0·27††
Mean	59·99*	58·29*	57·75*	60·53*	59·14	...	58·71*	57·67*	57·45*	58·93*	58·19	...
Increase	+1·70**		+2·78**				+1·04**		+1·48**			
Standard errors	*±0·139, †±0·170, **±0·197, ††±0·241						*±0·153, †±0·187, **±0·217, ††±0·265					
	Co 213 ±0·236						Co 312 ±0·277					
Light	66·49	64·76	65·06	66·17	65·62†	...	64·90	63·58	64·23	64·26	64·24†	...
Medium	66·82	65·08	65·90	66·00	65·95†	+0·33††	64·97	63·58	64·46	64·10	64·28†	+0·04††
Heavy	65·08	62·58	64·16	63·51	63·83†	—2·12††	64·04	62·38	64·00	62·43	63·21†	—1·07††
Mean	66·13*	64·14*	65·04*	65·23*	65·13	...	64·64*	63·18*	64·23*	63·60*	63·91	...
Increase	+1·99**		+0·19**				+1·46**		—0·63**			
Standard errors	*±0·136, †±0·167, **±0·192, ††±0·236						*±0·160, †±0·196, **±0·226, ††±0·277					

Setting of the mill.—In the case of the thinner varieties the extra tight setting yielded a significantly higher percentage of juice than did the 'tight setting'. In the case of Co 312, however, extra tight setting depressed the juice percentage significantly.

Speed of mill rollers.—The slow speed of mill rollers regulated by an easy pace of working bullocks was found invariably to give a significantly higher extraction than the fast speed obtained by driving the bullocks at a quicker pace.

Feeding of the mill.—The results obtained under different levels of feed were somewhat inconsistent and therefore these have been examined separately for each variety.

Katha.—The maximum extraction was obtained with medium feed, but the difference was significant only when compared with light feed. Heavy feed, however, when compared with either the light or the medium feed, showed no significant difference.

Co 285.—In this case the medium feed gave the largest percentage of juice, and there was a significant difference in the results from this as compared with those from light and heavy feeds.

Co 213 and Co 312.—In the case of these two varieties which belong to the thicker types of the medium canes, there was no significant increase in percentage juice on changing the feed from light to medium. A significant falling off in this figure was, however, noticeable in both cases when heavy feed was resorted to.

The results obtained show conclusively that the medium feed is the best both for the thin as well as the medium canes. In the case of thin canes, like Katha, there was a positive, though not significant, increase with heavy as compared with the light feed. The extraction with heavy feed when compared with the medium feed was, however, less, although the difference was statistically not significant. In the case of the thinner types of the medium varieties, such as Co 285, there was a significant decrease in extraction with the heavy feed as compared with the medium feed, but when heavy feed was compared with light feed there was a gain. With thicker varieties of the medium canes, such as Co 213 and Co 312, heavy feed, whether compared with the light or the medium feed, invariably depressed the extraction to a significant degree.

It was observed that in the case of heavy feed a small portion of partially crushed canes was usually found to slip off the crushing zone of the rollers, specially when the canes fed were bent or crooked instead of being straight. This slipping was specially pronounced when the speed was fast. On account of their curvature the crooked and bent canes have a tendency to push the other canes away from the rollers, thus resulting in low extraction. In the case of straight canes of thin varieties such a risk is practically absent. Further, thin canes when they are bent, can pass through the mills abreast of each other and may thus be subjected to a greater pressure than when they are passing singly as is usual with thicker types. It also happens that when the rollers move at high speed, there is insufficient time for the extracted juice to drain off the rollers and a part of it may be taken along with them. An appreciable amount of the juice becomes absorbed in the bagasse which passes out on the other side, and thus the juice percentage is lower than what it should be.

DIFFERENTIAL RESPONSES

Table V shows the responses to any particular factor in the presence and absence of any other.

TABLE V

Differential responses of various interacting factors influencing the percentage extraction of juice

—	Differential responses						
	Setting		Speed		Feed		
	T_1	T_2	E	F	L	M	H
				Katha			
Setting (T_2—T_1) .	..	..	+1·14*	+1·81*	+1·44*	+1·59*	+1·39*
Speed (E—F) .	+1·37*	+0·70*	..	..	+0·86*	+1·06*	+1·19*
Standard errors .	±0·307				±0·375		
				Co 285			
Setting (T_2—T_1) .	..	..	+3·07*	+2·50*	+2·97*	+3·28*	+2·10*
Speed (E—F) .	+1·42*	+1·99*	..	..	+0·81*	+1·84*	+2·46*
Standard errors .	±0·279				±0·341		
				Co 213			
Setting (T_2—T_1) .	..	..	—1·10	+0·47	+1·11*	+0·10	—0·65
Speed (E—F) .	+2·27*	+1·71*	..	..	+1·73*	+1·74*	+2·50*
Standard errors .	±0·272				±0·333		
				Co 312			
Setting (T_2—T_1) .	..	..	—0·34	—0·93*	+0·03	—0·36	—1·57*
Speed (E—F) .	+1·16*	+1·75*	..	..	+1·32*	+1·39*	+1·66*
Standard errors .	±0·320				±0·391		

In this table the method of using the standard errors for finding the significance of the responses to different factors, is the same as that employed in Table IV already discussed. In order to appreciate fully the response to speed in the presence and absence of the two degrees of setting, the case of Katha may be explained in some detail. As is well known a quantity is regarded as significant if it is greater than twice its standard error, and the difference between two quantities having the same standard error is significant if it is three times that standard error. The mean response to speed which is one half the sum of $+1\cdot37$ and $+0\cdot70$ or $+1\cdot04$ has a standard error $\pm \frac{0\cdot307}{\sqrt{2}} = \pm\, 0\cdot217$; and since this response is approximately five times its standard error, it is significant. The responses to speed in the presence of tight and extra tight settings are $+\,1\cdot37$ and $+0\cdot70$, each with a standard error of $\pm0\cdot307$. Both of these are therefore significant. The differential response or interaction which is the difference of these two is not significant, being only about twice the standard error of each.

Considering all the data presented in the table in the above manner, it was found that the responses due to any particular factor—in the presence and absence of the remaining two—were significant in a large number of cases. These have neen marked with an asterisk.

The responses to setting in relation to the two levels of speed were found to be positive and significant in the case of the two thinner varieties, *viz.*, Katha and Co 285. In the case of Co 312, this response of setting in the presence of fast speed although significant was negative. The responses to speed in the presence of the two types of setting were positive and significant in all cases.

The response to setting in relation to heavy feed was found to be significant in the case of Katha and Co 285. In the case of the remaining two comparatively thicker varieties, this response was negative and significant only in the case of Co 312. Considering the response to setting in the presence of light and medium feeds it was found that the medium feed for Co 213 and the light and medium feeds for Co 312 gave insignificant values.

The responses to speed in the presence of all the three levels of feed were in all cases positive and significant.

The interactions of feed with setting as well as with speed were found to be significant in a number of cases which are mentioned below :—

Katha.—There were no significant interactions in any case.

Co 285.—The interactions of setting with medium feed *versus* heavy and that of speed with light feed *versus* both the medium and the heavy feeds were significant.

Co 213.—The interactions of setting with the light *versus* medium or heavy feeds were significant.

Co 312.—The interactions of setting with the heavy *versus* light or medium feed were significant.

The interaction of speed and setting was found to be insignificant in all cases.

Complete information on the various interactions can be derived from the analyses of variance given in Table II, by splitting up the various degrees of freedom into their unitary elements in all possible ways.

The second order interaction between setting, speed and feed was found to be significant only in the case of Co 285.

It is generally believed that tightness of the mill is the main, if not the only, factor which regulates the amount of juice obtained from cane. The above results however, show that feed is no less important since this also indirectly regulates setting. In the case of the thin varieties, like Katha and Co 285, which is the thinnest of the medium canes, medium feed with extra tight setting gave the best extraction, but with thicker types of medium canes represented by Co 213 and 312 extra tightness, in a number of cases, resulted in a lower extraction, specially when the feed was heavy. Therefore, when dealing with thicker types of the medium canes, the choice should be in favour of the lower feed while in the case of the thinner types medium feed should be preferred. It must be recognised, however, that the canes of any variety which are usually crushed at one time vary in thickness. Therefore in the light of the conclusions arrived at in this investigation, the exact amount of feed capable of giving the maximum extraction will be a matter to be decided by the man on the spot. Further, easy pace of working bullocks undoubtedly gave higher extraction than the fast pace.

SUMMARY

1. The paper supplies information on the best conditions under which different varieties of canes could be crushed in a bullock-driven mill so as to yield the maximum quantity of juice.

2. In comparing different varieties of sugarcane with each other or in judging the effect of different kinds of treatments on the quality of cane, it is essential that the juice percentage which a variety is capable of yielding, be determined accurately. This is all the more necessary when the data from the analysis of juice are to be expressed as percentages on cane.

3. The amount of juice obtained depends not only upon the type of cane crushed but also upon certain other factors which prevail during crushing. Three such factors, *viz.*, (*a*) setting of the mill, (*b*) speed of the working bullocks, (*c*) the amount of feed, have been considered.

4. In order to bring into prominence the influence exerted by these factors individually or in their various combinations upon the extraction of juice, the samples for the purpose of this investigation were drawn from a population consisting of canes as uniform as possible.

5. The investigation was planned on the lines of a factorial design in agricultural field trials and four replications were provided for each treatment combination. This design made it possible to combine every one of a set of differential treatments with each one of the other sets and thus to obtain information with equal precision on the responses due to various factors studied. The paper illustrates how the application of factorial designs, originally meant to cover agricultural field trials, can be extended in various other directions.

6. The results from four samples of cane of both the thin and the medium varieties are reported and the data pertaining to each have been examined statistically.

7. It was found that the effects of the main treatments were significant in almost all cases. Slow speed was invariably found to give a higher extraction than the fast speed, and extra tight setting was better only in the case of thinner types. Of the three levels of feed, 'medium feed' gave the largest amount of juice.

8. The interaction of speed and setting was found to be insignificant throughout.

9. Feed whether in combination with speed or setting interacted significantly in most of the cases.

The authors wish to express their thanks to Mr. Balmokand, M.Sc., Assistant Professor of Physics and Mathematics for his valuable suggestions and help received in the preparation of this paper, and to the Deputy Director of Agriculture, Gurdaspur, for the supply of cane and crushing facilities.

REFERENCE

Ramji Narain, and Singh, A. (1937). *Ind. J. Agri. Sci.* **7**, 601

Appendix

In addition to the data presented in the foregoing note, work was also done on Katha at Rawalpindi and Co 285 at Lyallpur.

The crushing mills used at the two stations were Batala and Nahan respectively. The Co 285 studied at Lyallpur was slightly thicker than that at Gurdaspur. In spite of these differences the conclusion drawn from the study of these two are, in a very large number of cases, similar to those obtained at Gurdaspur. It has been found that medium feed is the best, although at Rawalpindi Katha showed a significant increase in the extraction with increase in the amount of feed. This was very likely due to the fact of the mill used being not properly lathed. Thus the main conclusion arrived at previously remains unaltered. Some data relating to these two types of canes are given below.

Effects of main treatments on percentage extraction of juice

Feeding of the mill	Speed		Setting		Mean	Increase
	E	F	T_1	T_2		
			Katha (Rawalpindi) ± *0·315*			
Light . .	56·63	54·52	53·45	57·70	55·57†	..
Medium . .	58·65	57·88	57·25	59·29	58·27†	+2·70††
Heavy . .	59·58	59·48	59·33	59·73	59·53†	+1·26††
Mean . .	58·29*	57·29*	56·68*	58·91*	57·79	..
Increase . .	+1·00**		+2·23**			
Standard errors	*±0·182, †±0·223, **±0·257, ††±0·315					
			Co 285 (Lyallpur) ±*0·197*			
Light . .	62·94	62·05	61·44	63·55	62·49†	..
Medium . .	64·03	63·82	62·94	64·90	63·92†	+1·43††
Heavy . .	63·56	62·66	63·30	62·93	63·11†	—0·81††
Mean . .	63·51*	62·84*	62·56*	63·79*	63·17	..
Increase . .	+0·67**		+1·23**			
Standard errors	*±0·114, †±0·139, **±0·161, ††±0·197					

Appendix—*contd.*

Differential responses of various interacting factors influencing the percentage extraction of juice

	Differential responses						
	Setting		Speed		Feed		
	T_1	T_2	E	F	L	M	H
	Katha (Rawalpindi)						
Setting (T_2—T_1) .	..	..	+2·69*	+1·77*	+4·25*	+2·04*	+0·40
Speed (E—F) .	+0·53	+1·45*	..	..	+2·11*	+0·77	+0·10
Standar errors .	±0·363				±0·445		
	Co 285 (Lyallpur)						
Setting (T_2—T_1) .	..	..	+1·26*	+1·21*	+2·11*	+1·96*	—0·37
Speed (E—F) .	+0·64*	+0·69*	..	..	+0·89*	+0·21	+0·90*
Standard errors .	±0·228				±0·279		

A HYPODERMIC SYRINGE FOR USE WITH HAND REFRACTOMETER IN SUGARCANE

BY

K. L. KHANNA

Sugarcane Research Scheme, Bihar

(Received for publication on 16th May 1938)

(With Plate LVII and one text-figure)

Ever since the invention of the Zeiss Hand Refractometer and extension of its use for determining ripening of cane in the field, in different sugarcane countries, a number of devices have been developed by individual workers for taking juice sample from cane stalks. Thus Verret and Mangelsdorf [1928], Bond [1930] and Lennex [1935] in Hawaii; Ibarra [1932] in Venezuela; Craig [1931, 1934] in Mauritius; Davis [1932, 1934] in Porto Rico and Moet [1934] in Java used the 'corer' device and the press either as originally supplied by the Carl Zeiss Company or as modified by them to suit particular conditions. Lee [1932] reported an improvement consisting of a lancet of non-rusting brass with a two-inch long point which had a groove extending right through. For taking juice sample the lancet was jabbed obliquely upwards in the cane and permitted to rest for a few seconds during which time juice trickled into the groove in the lancet point. Levert and his associates [1932, 1934] in Java developed an improvement known as 'Gempol Knife' or 'punch' which, when thrust into the cane stalk, allowed a drop of juice to pass through an opening into reservoir. Mercado [1934] in Philippines constructed an ingenious appliance consisting of a pair of pliers on the inner surface of which was a blade to cut into the rind and a small tapering tube through which the juice passed for collection.

Although some of these devices proved satisfactory for the purpose of taking juice sample from growing stalks, the wound that they left in the punctured stalk was too big to permit of any further readings being taken on the progress of ripening in the same internode. Viswa Nath [1919] was probably the first to devise a suitable technique to serve the purposes of an intensive study on a particular internode during the course of ripening although reference of his work does not seem to have been either available or taken note of by workers in other sugarcane countries. Briefly described, his instrument comprised a modified hypodermic needle, the short open end of which was plugged with melted tin and a small hole bored on the side of the needle a little behind the point. This needle, when inserted in a slightly slanting position into an internode and pressed, easily secured two drops of juice, while on account of its fine and narrow chisel end, injury to the internode was appreciably reduced.

There was, however, the difficulty of cleaning the needle frequently as it soon got blocked with pieces of cane magasse. Also, as would appear, the quantity of juice, that this needle as well as the other devices mentioned above secured from an internode, was strictly in proportion to the quantity of internodal tissue ruptured by them and the pressure applied while taking the sample, so that certain amount of injury was unavoidable. The author had since 1930 an idea to combine in a new device the essential of Viswa Nath's [1919] needle point fitted with a suction and pressure mechanism so as,

(*i*) to minimise the actual rupturing of cells and to permit of purer juice samples being drawn by suction;

(*ii*) to get the sample of juice drawn dropped on the refractometer prism easily by pressure;

(*iii*) to get over the difficulty of having to clean the needle point every time it is used;

and by having a number of removeable piercing points to suit canes of different hardness and other special purposes, such as intensive study on a particular internode during the course of ripening, etc.

(*iv*) to make both the experimental as well as the large-scale field testing an easier task.

With this end in view the author had suggested the need for a device similar to a hypodermic syringe in 1931 to the Sugar Technologist of the Imperial Council of Agricultural Research, who had approved of the idea but had failed to get such an instrument anywhere in the market.

In 1932 the opening of the Sugarcane Research Station in Bihar and Orissa with the funds granted by the Imperial Council of Agricultural Research afforded ample opportunities to the author to develop the desired instrument and try it out both on experimental as well as large-scale field trial studies [Khanna, 1933, 1934]. The hypodermic syringe (Fig. 1, Plate LVII) described below has been now in use at the Station for the past three seasons and has justified the claims originally postulated. The results obtained (Table I) have demonstrated that the juice samples withdrawn by the hypodermic syringe are not only purer but they are also less liable to fluctuations than are those obtained by either the corer needle or the punch press. Also the brix values obtained in the former case agree more closely with the mill-juice brix of the sampled internode as compared to those in the latter two cases, the punch press juices showing significantly lower values.

NEW INSTRUMENT DESCRIBED

The new instrument (Fig. 1) is based essentially on the principle of hypodermic syringe and comprises a hollow cylinder (cy) fitted with a combined suction and pressure plunger (p), the plunger being fitted on the outside with a button end (e) and spring (s), arranged to withdraw the plunger to the limit of its travel. The plunger is prevented from withdrawing completely from the cylinder by means of a cap-nut (cn) screwed onto the top end of the cylinder. Fitted to the cylinder immediately below the cap-nut is a handle (h) of convenient shape to afford firm grip to the fingers. The bottom end of the cylinder is fitted with a screwed cap (sc) which terminates in a hollow point (po) with a sharpened end and an orifice (o) on one side, the orifice being a short distance behind the point. The screwed caps are removeable and of three types (Fig. 1, a, b and c) to suit canes of different rind hardness and special studies.

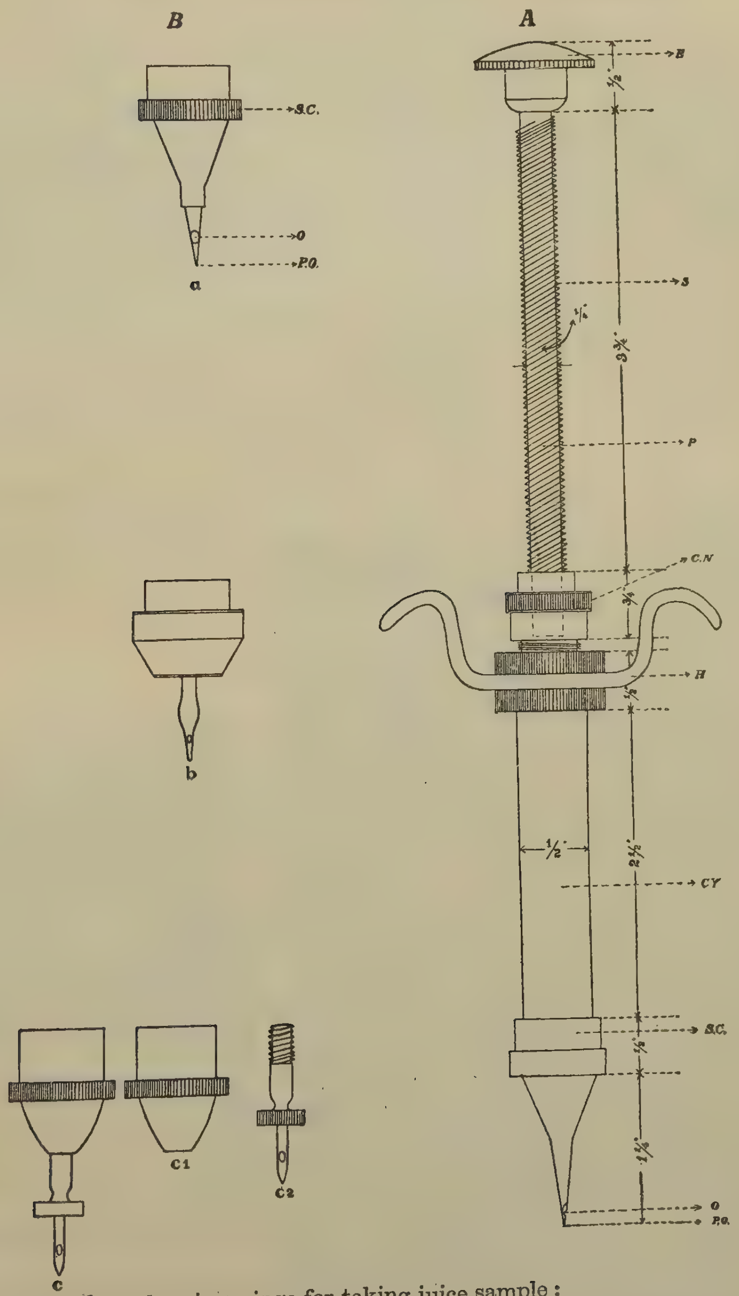


FIG. 1 A. A hypodermic syringe for taking juice sample: E = Button end, H = Handle, S = Spring, Cy = Cylinder, P = Plunger, Sc = Screwed cap, Cn = Cap-nut, O = Orifice, Po = Point with sharpened end,

B = Needle points of different types:

(*a*) to suit hard canes with high fibre content; (*b*) to suit soft canes with comparatively low fibre content; (*c*) to serve the purposes of intensive study on a particular internode during the course of ripening; (c^1) removeable screwed cap; (c^2) Cycle valve-pin modified to serve as micro-needle point to reduce injury to the minimum

In use the instrument is gripped and the plunger pressed down to its full extent within the cylinder (Plate LVII, fig. 1) compressing the spring. The sharpened end of the point is then inserted into the cane to a sufficient depth to completely cover the orifice in the case of uncollared piercing points, while up to only the collar in others (Plate LVII, fig. 3) and the plunger is then release to its full travel (Plate LVII, fig. 2). By so doing a fair quantity of juice can be withdrawn, on account of suction, without much difficulty. The plunger is once again pressed down and the contents of the cylinder dropped on to the lower half of the prism of the hand refractometer (Plate LVII, fig. 3), the two halves immediately closed, and reading taken by holding the instrument against the light. With a little practice an observer (Plate LVII, g. 4) soon masters the technique and can go over much larger population than hitherto possible in a day.

ACKNOWLEDGMENTS

The author is grateful to the Imperial Council of Agricultural Research under whose scheme for Surgarcane Research in Bihar and Orissa the instrument has been developed and to Messrs. Arthur Butler and Company, Muzaffarpur for making the instrument in their workshops.

REFERENCES

Bond, J. S. (1930). *Hawaii. Planters' Rec.* **34**, No. 3, 331

Craig, N. (1931). *Int. Sug. J.* **33**, No. 385, 14

——— (1934). *Int. Sug. J.* **36**, No. 426, 235-236

Davis, R. L. (1932). *Proc. 4th Cong. Int. Sugarcane Technol. (Porto Rico)*

——— (1934). *Agric. Notes P. R. Agric. Expt. Stn. Mayaguez* **67** (Abst. in *F.A.S.* **30**, No. 2, 69)

Ibarra, R. A. (1932). *Proc. 4th Cong. Int. Sugarcane Technol. (Porto Rico)*

Khanna, K. L. (1933). *Dept. Agric. B. & O. Bull.* No. **5**, 19

——— (1934). *Dept. Agric. B. & O. Bull.* No. **6**, 32

Lee, A. (1932). *Proc. 4th Cong. Int. Sugarcane Technol. (Porto Rico)*

Lennex, G. G. (1935). *Hawaii. Planters' Rec.* **39**, No. 1, 13-18

Levert, L. and Associates (1932). *Archief.* **40**, No. 26, 629-647 (Abst. in *F.A.S.* **27**, No. 10, 452)

——— (1934). *Archief.* **42**, No. 4, 83-115 (Abst. in *F.A.S.* **29**, No. 5, 167)

Mercado, Toribio (1934). *Sug. News* **15**, No. 6, 303-307 (Abst. in *Int. Sug. J.* **36**, No. 430)

Moet, K. J. (1934). *Archief.* **42**, No. 7, 193-211 (Abst. in *Int. Sug. J.* **36**, No. 428, 320)

Verret, J. and Mangelsdorf, A. J. (1928). *Hawaii. Planters' Rec.* **32**, No. 4, 427-433

Viswa Nath, B. (1919). *Agric. J. Ind. Sp. Ind. Sci. Cong. No.* **14**, Pt. III, 441

HYPODERMIC SYRINGE IN USE

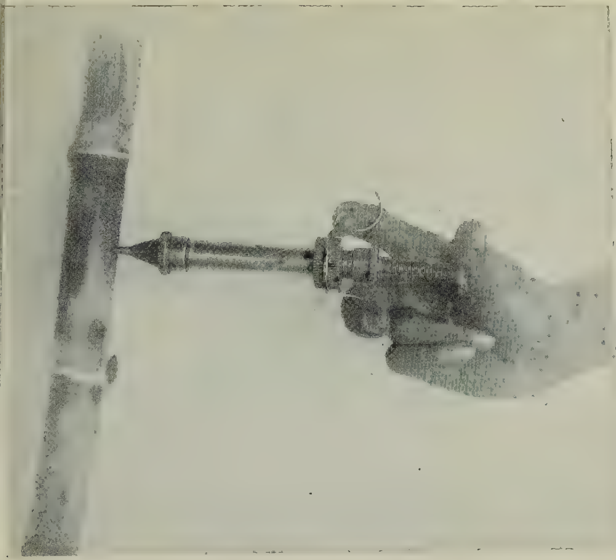


FIG. 1. Pressing spring plunger while puncturing

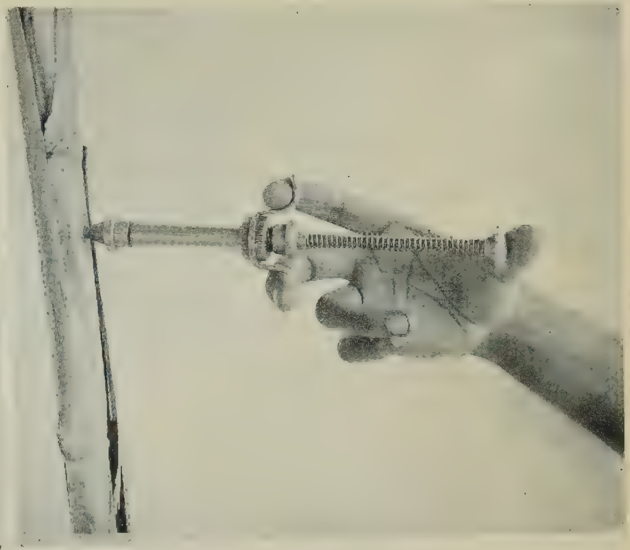
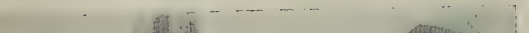


FIG. 2. Releasing spring plunger to allow suction of juice



IG. 3. Pressing spring plunger to drop the contents on the refractometer prism

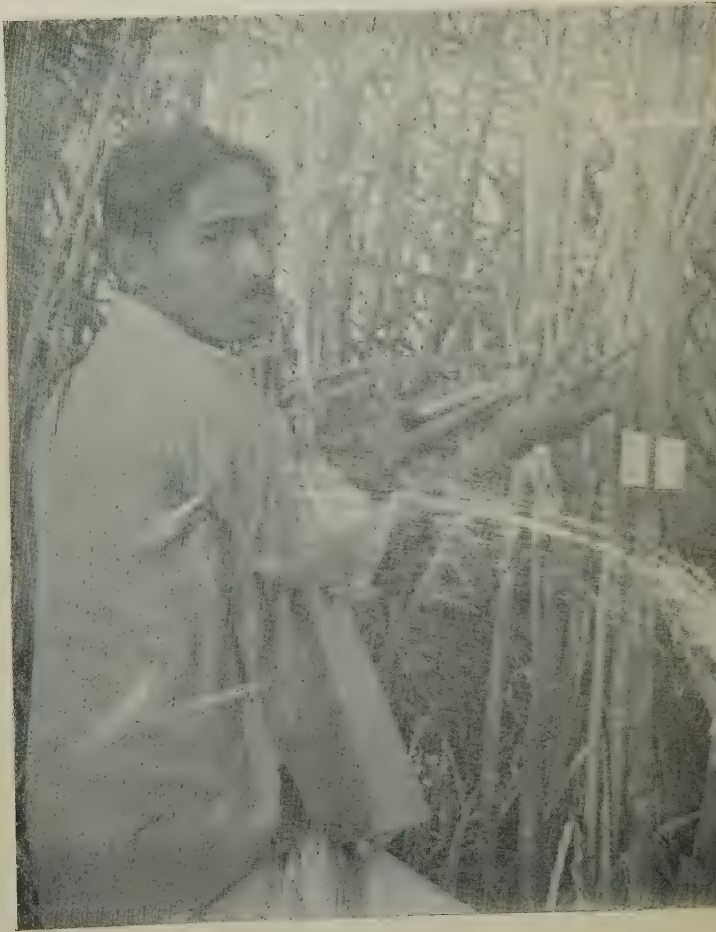


FIG. 4. Position of the observer, hypodermic syringe and the hanc refractometer

TABLE I

Hand-refractometer brix of juice samples drawn by different devices

(a) Tests made on the 12th December, 1937

Serial No. of test	Corer needle supplied by the Carl Zeiss Company	Punch press	Hypodermic syringe designed at the Station	Mill juice analysis of sampled internode
1	14·8	14·4	15·0	15·2
2	14·4	14·0	14·6	14·4
3	15·2	15·0	15·2	15·4
4	14·8	14·4	15·2	15·4
5	14·6	14·4	15·2	15·0
6	15·6	15·4	15·8	15·4
7	14·0	14·0	14·4	14·6
8	14·4	13·8	14·4	14·2
9	13·8	13·6	14·0	14·2
10	15·4	15·0	15·4	15·4
11	14·6	14·4	14·8	14·6
12	14·2	14·2	14·4	14·6
13	14·4	14·0	14·6	14·8
14	16·0	15·4	16·0	16·2
15	15·6	15·2	15·8	15·8
16	15·0	15·4	15·6	15·6
17	14·8	14·6	15·0	14·8
18	14·8	14·4	15·0	14·8
19	14·0	13·8	14·2	14·0
20	14·8	14·2	15·2	15·0
Mixed juice brix	14·4	14·2	14·8	14·5
Per cent pol.	10·89	10·74	11·28	11·10
Per cent purity	75·6	75·6	76·2	76·0

TABLE I—*contd.*

(b) Tests made on the 25th January 1938

Serial No. of test	Corer needle supplied by the Carl Zeiss Company	Punch press	Hypodermic syringe designed at the Station	Mill juice analysis of sampled internode
1	17·4	17·0	17·6	17·4
2	17·8	17·4	18·2	18·0
3	16·8	16·0	17·2	17·0
4	17·8	17·8	17·8	17·6
5	17·6	17·0	17·8	17·8
6	18·2	17·8	18·6	18·4
7	16·6	16·0	17·0	16·8
8	17·6	17·2	18·0	18·0
9	18·4	18·0	18·4	18·2
10	17·6	17·6	18·0	18·0
11	18·4	17·8	18·4	18·2
12	17·8	17·6	18·2	18·2
13	18·0	17·4	18·4	18·2
14	17·0	16·8	17·2	17·4
15	18·4	18·0	18·6	18·6
16	17·8	18·0	18·4	18·2
17	18·0	18·0	18·4	18·0
18	18·2	17·6	17·8	17·8
19	17·0	16·6	17·4	17·4
20	17·4	16·8	17·8	17·6
Mixed juice brix	17·2	16·9	17·8	17·7
Per cent pol.	14·52	14·17	15·18	15·03
Per cent purity	84·4	83·8	85·3	84·9

TABLE I—*contd.*

(c) *Tests made on 12th March 1938*

Serial No. of test	Corer needle supplied by the Carl Zeiss Company	Punch press	Hypodermic syringe designed at the Station	Mill juice analysis of sampled internode
1	19·4	19·0	19·8	19·4
2	20·2	19·4	20·4	20·0
3	18·8	18·2	19·2	19·2
4	19·0	18·6	19·6	19·6
5	20·0	19·6	20·0	19·8
6	19·2	19·0	19·8	19·6
7	18·8	18·8	19·0	19·2
8	20·2	20·0	20·4	20·6
9	19·2	19·0	19·6	19·6
10	19·8	18·8	19·8	19·4
11	19·6	19·2	20·0	20·2
12	19·8	18·8	19·4	19·2
13	19·2	18·8	19·0	19·0
14	20·8	20·0	20·6	19·2* Borer infested.
15	19·6	19·2	20·0	20·0
16	19·0	19·4	20·0	20·0
17	19·0	18·8	19·2	19·2
18	19·8	19·8	20·0	20·4
19	20·0	19·4	20·4	20·4
20	19·2	18·8	19·6	19·8
Mixed juice brix	19·0	18·6	19·6	19·4
Per cent pol.	16·72	16·38	17·29	17·16
Per cent purity	88·0	88·1	88·7	88·5

TABLE I—*concld.*

(d) Tests made on the 2nd April 1938.

Serial No. of test	Corer needle supplied by the Carl Zeiss Company	Punch press	Hypodermic syringe designed at the Station	Mill juice analysis of sampled internode
1	22·6	22·2	23·0	22·6
2	22·6	22·6	23·0	22·8
3	23·2	22·8	24·0	23·8
4	23·2	23·0	23·6	23·8
5	22·6	22·2	23·0	23·0
6	22·2	22·0	22·4	22·6
7	21·8	21·4	22·0	22·0
8	22·2	21·6	22·4	22·6
9	22·8	21·8	23·0	23·2
10	22·8	22·4	22·8	22·8
11	23·2	22·8	23·4	23·0
12	22·2	22·0	22·8	22·6
13	24·2	23·8	24·0	23·8
14	23·2	23·0	23·6	23·8
15	23·0	22·8	23·0	23·2
16	23·0	22·8	23·8	23·6
17	23·2	22·8	23·6	23·8
18	22·4	22·0	22·6	22·4
19	22·8	22·4	22·8	22·6
20	22·2	22·0	22·8	22·8
Mixed juice brix .	22·6	22·5	23·0	23·1
Per cent pol.	18·98	18·65	19·46	19·57
Per cent purity .	84·0	82·9	84·6	84·7

STUDIES ON THE ROOT-ROT DISEASE OF COTTON IN THE PUNJAB

V. CONFIRMATION OF THE IDENTITY OF *RHIZOCTONIA BATATICOLA*

BY

JAI CHAND LUTHRA, M.Sc., D.I.C. (Lond.), I.A.S.

Professor of Botany

AND

R. SAHAI VASUDEVA, B.Sc., Ph.D. (Lond.), D.I.C. (Lond.)

Assistant Cotton Mycologist, Punjab Agricultural College and Research Institute, Lyallpur

(Received for publication on 17th March 1938)

(With three text-figures)

Introductory

Several thousand isolations were made from time to time from different parts of the root-system of diseased cotton plants affected with root-rot. For these isolations diseased plants were obtained from almost all the cotton-growing districts of the province. The parasitism of the causal fungi—two species of *Rhizoctonia*, *i.e.*, *Rhizoctonia solani* Kuhn. group and *Rhizoctonia bataticola* 22 (*a*), was established [Vasudeva, 1935].

Rhizoctonia *sp. 22* (*a*).—This fungus is rather problematical. It has so far been provisionally called *Rhizoctonia bataticola*. Present investigation was undertaken to determine the specific name of this fungus. The following allied fungi were used for comparative study and to begin with hyphal tip cultures [Brown, 1924] were made to ensure their purity.

	Fungus		Source
1. 3113 c	*Rhizoctonia bataticola* (Taub.) Butler,	from banana roots.	Hopkins, J. C. (Rhodesia).
2. 998	*Rhizoctonia bataticola* (Taub.) Butler,	from lemon roots.	
3. LIBR	*Rhizoctonia lamellifera* Small,	from lucerne roots.	

Cultural characters of *Rhizoctonia* sp. 22(a)

The fungus was grown on three media—cotton root synthetic* [Vasudeva, 1936], Richards' agar and potato extract—at 20°, 25°, 30° 35° and 40°C.

---

* Glucose 20 grms., peptone 2·9 grms., K_3PO_4 1·9, Ca_3 $(PO_4)_2$ 0·9, $MgSO_4$ 0·4, NaCl 0·6, $FeCl_3$ a trace, distilled water to make up 1,000 c.c.

At the same time, *R. bataticola* strains 3113 *c* and 998 and *R. lamellifera* were grown under identical conditions for comparison.

Rhizoctonia sp. 22 (*a*) closely resembles *Rhizoctonia bataticola* strain 3113 *c* and, to a lesser degree, strain 998. On all media under optimum temperature conditions it produces a white colony with plenty of aerial mycelium, which later turns dark grey, thus differing from *Rhizoctonia lamellifera* but agreeing with *R. bataticola* (3113 *c*) in the following particulars :—

(*i*) Abundance of sclerotia.

(*ii*) Amount of aerial mycelium.

(*iii*) Similar growth-rate at different temperatures on a variety of media.

The cultural characters of the various fungi on cotton root synthetic agar after four days' growth are summarised in Table I. These characters are almost constant on the other media tested.

TABLE I

Cultural characters of the fungi on cotton root synthetic agar

Fungus	Temperature (°C.)	Growth	Aerial mycelium	Colour	Sclerotia formation
22 (*a*)	20	Poor	*Nil*	White	*Nil*
	25	Good	Little	White	Fair
	30	Abundant	Plenty	White	Abundant
	35	Good	Plenty	White	Good
	40	*Nil*	*Nil*	*Nil*	*Nil*
3113*c*	20	Poor	*Nil*	White	*Nil*
	25	Good	Little	White	Fair
	30	Abundant	Plenty	White	Abundant
	35	Good	Plenty	White	Good
	40	*Nil*	*Nil*	*Nil*	*Nil*
998	20	Poor	*Nil*	White	*Nil*
	25	Fair	Little	White	*Nil*
	30	Abundant	Little	White	*Nil*
	35	Poor	Little	White	*Nil*
	40	*Nil*	*Nil*	*Nil*	*Nil*
R. lamellifera	20	Good	*Nil*	..	Fair
	25	Good	*Nil*	..	Fair
	30	Very poor	*Nil*	..	*Nil*
	35	*Nil*	*Nil*	*Nil*	*Nil*
	40	*Nil*	*Nil*	*Nil*	*Nil*

Fig. 1, which gives the growth after three days on cotton root synthetic at different temperatures, illustrates that strain 22 (*a*) and 3113 *c* agree very closely in the rate of growth and in the position of the optimum. Similar curves which were prepared for Richards' agar and potato extract agar showed exactly the same relationship.

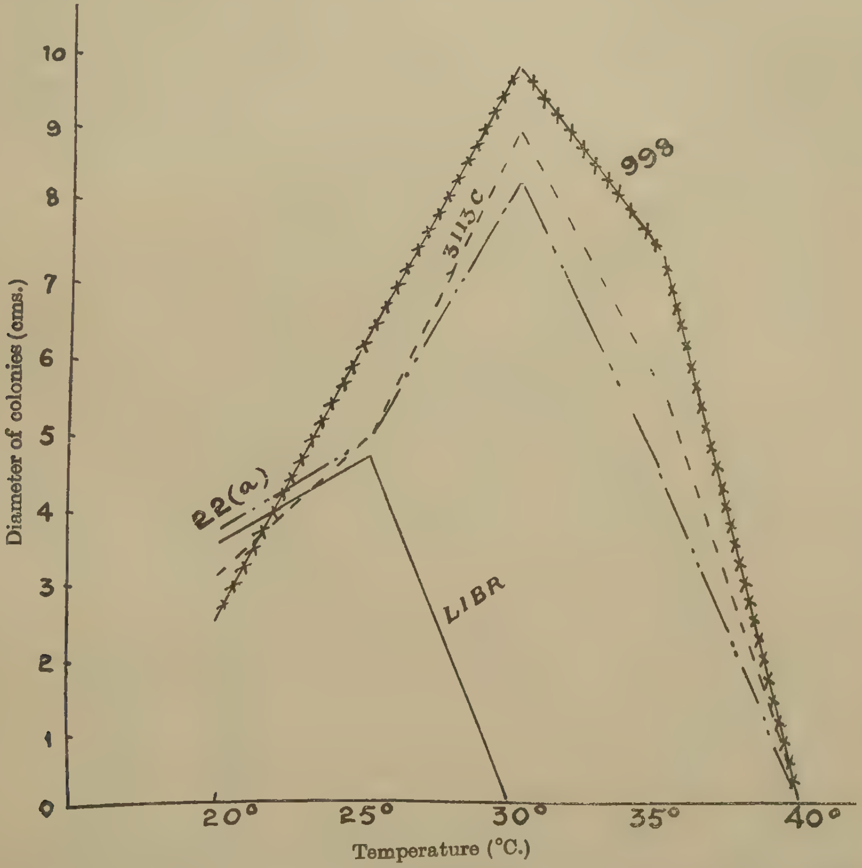


Fig. 1. Growth of certain *Rhizoctonia* cultures on cotton root synthetic agar (3 days growth)

It may, however, be mentioned that *Rhizoctonia* sp. 22 (*a*) has a tendency to throw out saltants. Richards' agar in three plates out of fifty-one, in which the layer of medium was poured shallow, gave rise to sectors. Such sectors were not observed in deep-poured plates [Christensen, 1926]. The method of growing the cultures on a shallow medium magnifies the difference between saltant and parent.

It is still a matter for further investigation whether the sectors produced in cultures of 22 (*a*) are true saltants or whether they are 'false' and revert back to the parent frequently after the manner of *Fusarium fructigenum* [Vasudeva, 1930].

The effect of acidity and alkalinity on the growth of the fungi was studied by comparing their growth rates on cotton root synthetic agar prepared with different degrees of acidity and alkalinity by addition of malic acid and sodium bicarbonate respectively. Eleven modifications of the medium were set up showing a series of acidity and alkalinity. The Petri dishes were inoculated in quadruplicates and incubated at 30°C. The linear rates of growth were measured from day to day. Fig. 2, which gives the growth of *Rhizoctonia* sp. 22 (*a*), *R. bataticola* (3113 *c*) *R. bataticola* (998) and *R. lamellifera* over a range of acidity and alkalinity, shows that *Rhizoctonia* sp. 22 (*a*) and *R. bataticola* (3113*c*) are very similar in their sensitiveness to acidity or alkalinity in the medium and that both grow strongly in media of *p*H 4-8.

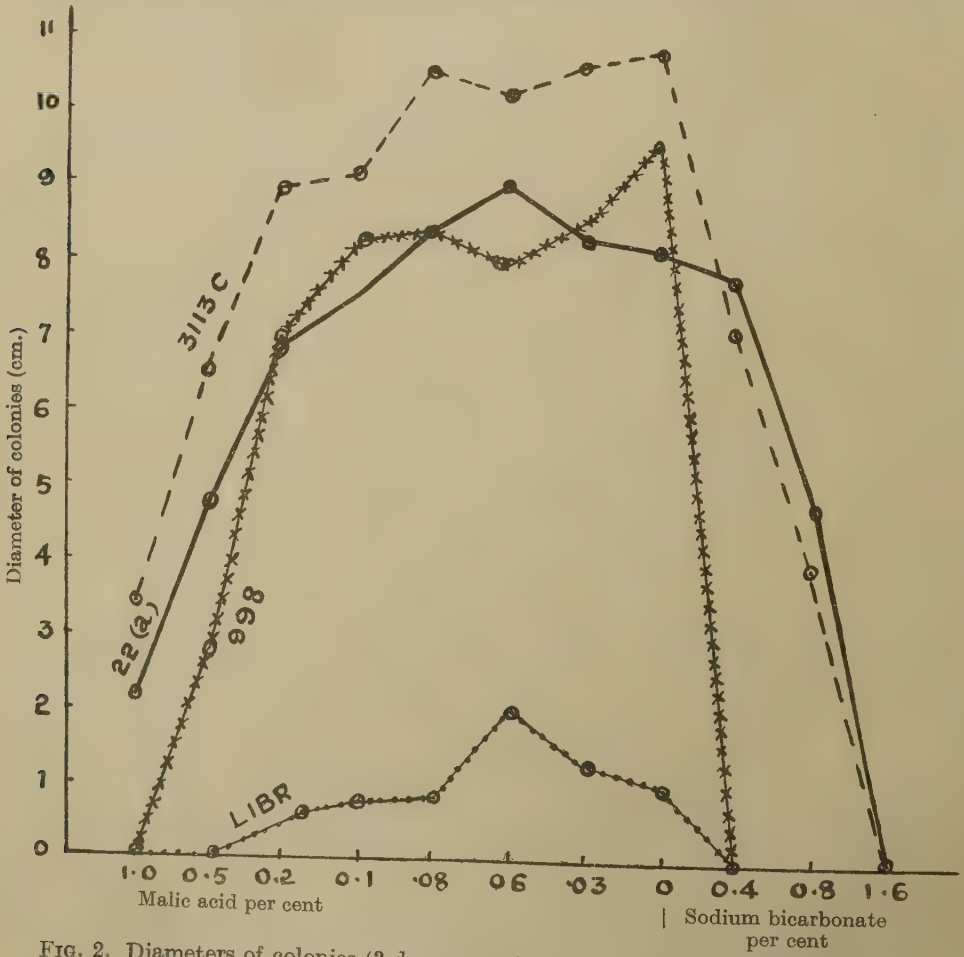


FIG. 2. Diameters of colonies (3 days growth) of *Rhizoctonia* cultures in media containing varying amounts of acid and alkali (medium, cotton root synthetic agar)

Measurements of sclerotia and hyphae of the fungi obtained from fifteen days' old cultures on cotton root synthetic agar (30°C.) were carried out. Diameter of sclerotia and hyphae of *Rhizoctonia* sp. 22 (*a*), *R. bataticola* (3113 *c*) *R. bataticola* (998) and *R. lamellifera* are given in Table II.

TABLE II

Measurements of sclerotia and hyphae from fifteen days' old cultures, on cotton root synthetic agar

Fungus	Diameter of sclerotia		Breadth of hyphae	
	Range (μ)	Ave. of 100 (μ)	Range (μ)	Ave. of 100 (μ)
Rhizoctonia sp. 22(*a*) . .	75-180	105·45±2·23	3·3-4·2	3·381±0·026
R. bataticola (3113 *c*) .	75-180	104·25±2·33	3·3-6·6	3·794±0·029
R. bataticola (998) . .	. .	. .	4·2-8·2	5·484±0·171
R. lamellifera (LIBR) .	6·6-16·5	9·90±1·79	2·0-3·3	3·241±0·023

It is obvious from the data that *Rhizoctonia* sp. 22 (*a*) and *R. bataticola* (3113 *c*) lie close as to the size of sclerotia and breadth of hyphae.

The sclerotia and hyphae of *Rhizoctonia* sp. 22 (*a*) and *R. bataticola* (3113 *c*) from seven days' old cultures are shown in Fig. 3. The sclerotial and hyphal characters of both are similar except that the hyphae of 3113 *c* are broader and possess fewer septa.

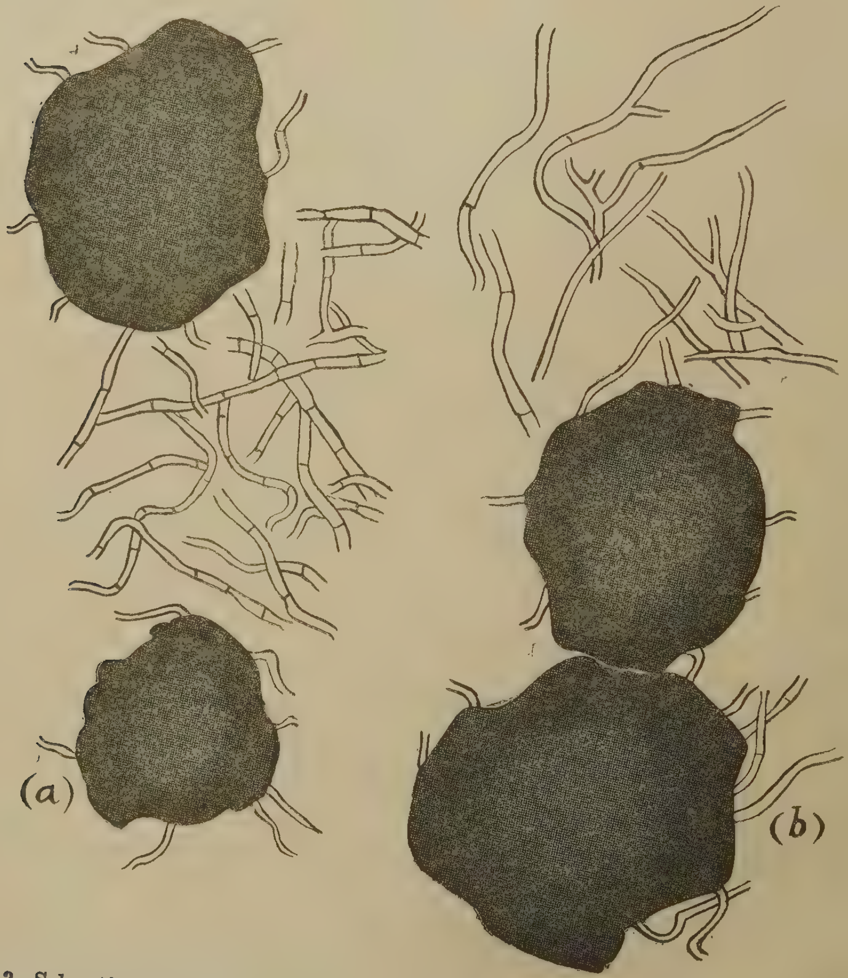


FIG. 3. Sclerotia and hyphæ of (*a*) *Rhizoctonia* sp. 22*a* and (*b*) *Rhizoctonia ataticola* (3113*c*) from seven days' old cultures (Camera lucida drawing × 260)

PATHOGENICITY OF THE FUNGUS

This was tested on cotton plants growing in pots. Inoculations with the fungi under study were carried out under controlled conditions and throughout plants of variety 43F (*Gossypium hirsutum*) were used. Roots of the cotton plants growing in pots were exposed by washing off the soil around the roots up to a depth of about three to five inches. The inoculum was added in the form of pure cultures growing on sterilized paddy, covered up with sterile soil and irrigated freely. Controls were treated similarly except that no inoculum was added. Every possible care was taken to maintain aseptic conditions throughout the course of these experiments.

In the first experiment, inoculated plants which were twenty days old were kept at a constant temperature of 30°C. In the second and third experiments, the inoculated plants were thirty-five and fifty-one days old respectively and were kept in a glass house where the temperature was subject to fluctuation. The loss of moisture on account of evaporation was made up by irrigation every day.

Results of three inoculation experiments carried out with *Rhizoctonia* sp. 22 (*a*), *R. bataticola* (3113 *c*), *R. bataticola* (998) and *R. lamellifera* (LIBR) are given in Table III.

TABLE III

Pathogenicity tests of various fungi

Fungus	Experiment I			Experiment II			Experiment III		
	Total plants inoculated	Plants killed	Percentage mortality	Total plants inoculated	Plants killed	Percentage mortality	Total plants inoculated	Plants killed	Percentage mortality
Rhizoctonia sp. 22(*a*) . .	12	10	83·33	43	34	79·09	17	12	70·58
R. bataticola (3113 *c*) . .	14	0	0	48	0	0	9	0	0
R. bataticola (998) . .	20	3	15·00	64	9	14·06	25	1	4·00
R. lamellifera (LIBR). .	12	0	0	41	0	0	16	0	0
Control	27	0	0	40	0	0	40	0	0

Rhizoctonia sp. 22 (*a*) attacked vigorously, whereas *Rhizoctonia bataticola* (3113*c*) and *R. lamellifera* failed to produce any symptoms of attack. Strain 998 is a comparatively weak parasite under the conditions of these experiments.

Rhizoctonia sp. 22(*a*) is very similar to the named culture of *Rhizoctonia bataticola* (3113 *c*) banana strain in its cultural characters, but as regards pathogenicity both are quite distinct.

Rhizoctonia sp. 22(*a*) is therefore a strain of *Rhizoctonia bataticola* (Taub.) Butler. A sample culture was also sent to Mr. S. F. Ashby of Imperial Mycological Institute, Kew, who confirmed the identification.

The investigation was carried out in connection with the scheme financed by the Indian Central Cotton Committee.

REFERENCES

Brown, W. (1924). *Ann. Bot.* **38**, 401-404

Christensen, J. J. (1926). *Univ. of Minn. Agric. Expt. Stn. Tech. Bull.* **37**, 1-101

Vasudeva, R. Sahai (1930). *Trans. Brit. Myc. Soc.* **15**, 96-101

——————— (1935). *Ind. J. Agric. Sci.* **5**, 496-512

——————— (1936). *Ind. J. Agric. Sci.* **6**, 904-916

BIOLOGY AND GENERAL MORPHOLOGY OF *LEUCOPIS GRISEOLA* FALL. (CHAMAEMYIDAE, DIPTERA), AN IMPORTANT PREDATOR OF *APHIS GOSSYPII*, AND SOME OTHER APHID PESTS OF CROPS

BY

HEM SINGH PRUTHI, M.Sc., Ph.D. (Cantab.), F. N. I.
Imperial Entomologist

AND

H. L. BHATIA, M.Sc.
Assistant to the Imperial Entomologist, New Delhi

(Received for publication on 22nd March 1938)

(With Plate LVIII)

Introductory

Last year, in the experimental plots under cotton of the Imperial Agricultural Research Institute, New Delhi, the attack of *Aphis gossypii* appeared about the middle of October and lasted till *kapas* was picked in the latter part of January. During November and December the larvæ of a dipterous fly were found actively predating upon nymphs of this pest. The flies reared from the larvæ have been identified as *Leucopis griseola* Fall. A perusal of available literature shows that this species is widely distributed in Europe, Egypt and America, and this is the first record from India. Smulyan [1919] recorded it as predating on the apple aphid, *Aphis prunifoliae*, in Virginia; Essig [1922] reared flies of this species from leaves of 'musk melon' infested with *Aphis gossypii*; Vasilev [1922] observed it predating on *Aphis anthrisci* on carrot in Russia and Smith [1923] bred it from clover aphid, *Anuraphis bakeri*, in America.

Several other species of the genus *Leucopis* are fairly well known as predators on aphids and coccids. For instance, *L. nigricornis* [Fenton, 1917] and *L. annulipes* [Bollow, 1917] are important predators of the common European scale, *Eulecanium* (*Lecanium*) *corni*; the former species also preys on *Pulvinaria psidii* in Florida [Berger, 1918]. *L. bella* is at present by far the most important known enemy of *Pseudococcus citri* and also attacks *Chrysomphalus aurantii* in California [Smith 1917, 1921]. *L. africana* Mall. is a predator of *Pseudococcus citri* in Africa [James, 1934]. *L. obscura* Hal. is an important natural enemy of the fir-tree aphid, *Adelges* (=*Chermes*) *pini* (L.), in Europe [Balch, 1934]. Attempts have been made to introduce this predator into several countries, *e.g.*, Canada, New Zealand and Australia, and it has been successfully established in Canada.

So far only two species of *Leucopis* have been described from the Indian region, *viz.*, *L. sordida* from Tibet [Becker, 1907] and *L. luteicornis* from Coimbatore [Malloch, 1924]. The latter species was found attacking the 'rain tree' mealy bug, *Phenacoccus iceryoides*. Cherian [1935] recorded a species of *Leucopis* predating on aphids on cotton, sorghum, *Pennisetum typhoideum* and *Dolichos lablab* in the Madras Presidency.

HABITS AND ECONOMIC STATUS OF *LEUCOPIS GRISEOLA*

At Delhi the small grayish flies of this species were usually observed in large numbers during November and December hovering on cotton plants between 3 and 5 P.M., when they oviposited amongst colonies of *Aphis gossypii*. A large number of leaves infested with the aphid were examined for the eggs of the predator from time to time. It was found that on leaves slightly infested with the aphid the number of eggs varied from one to eight on each leaf, on those with moderate infestation two to twenty-eight eggs were observed on each leaf, while the most heavily infested leaves had eleven to thirty-eight eggs each.

The young larva feeds voraciously on the aphid nymphs. The larva sometimes takes shelter beneath the body of the nymph on which it preys. A single larva devours seventy to hundred aphid nymphs during its life. The larva is not cannibalistic.

In our parasite laboratory several flies of the predator were liberated on cotton plants infested with *Aphis gossypii*. They laid eggs on leaves amongst colonies of aphids and the larvæ developing from the eggs killed off a large number of aphid nymphs in a short time. Thus the predator seems to be a powerful enemy of this pest. Its potentialities in the field have yet to be thoroughly investigated.

Another predator of *Aphis gossypii* at Delhi is *Syrphus confrator* Wied. (Syrphidae). This is a well-known enemy of this aphid at Pusa. During the last cotton season the Syrphid predator was much less common than *Leucopis griseola*. Other aphids on which *Leucopis griseola* has been observed by us to prey upon at Delhi are the barley and wheat aphid, *Macrosiphum granarium*, the potato aphid, *Myzus persicae*, and the aphids (yet unidentified) which attack hollyhock, *palak* and mustard.

DESCRIPTION AND DURATION OF VARIOUS STAGES IN THE LIFE-HISTORY

Oviposition and incubation period.—The gravid females collected from the field readily laid eggs in the laboratory. In December and January the maximum number of eggs laid by one female was forty-two during a period of four weeks, and the maximum number of eggs laid by one female in one day was seven. The incubation period at this time of the year inside the laboratory having average maximum and minimum temperatures of 61°F. and 57·7°F. respectively was four to seven days and seven to eight days respectively (average of ten observations).

The egg (Plate LVIII, fig. 1) is elongated oval and more or less spindle-shaped. It measures $0{\cdot}5 \times 0{\cdot}2$ mm., being broader at the posterior end and gradually narrowing towards the anterior pole, at the tip of which there is the minute micropyle. The chorion is marked by longitudinal striations with

EXPLANATION OF PLATE LVIII

Fig. 1. The egg (0·5 mm. × 0·2 mm.) (×53)

Fig. 2. The newly hatched larva (0·6 mm. × 0·2 mm.) (×53)

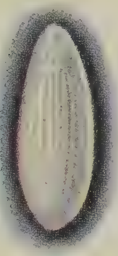
Fig. 3. The full-grown larva (4·0 mm. × 1·0 mm.) (×26)

Fig. 4. The head of the full-grown larva (0·3 mm. × 0·12 mm.) (×175)

Fig. 5. The puparium (2·0 mm. × 0·75 mm.) (×26)

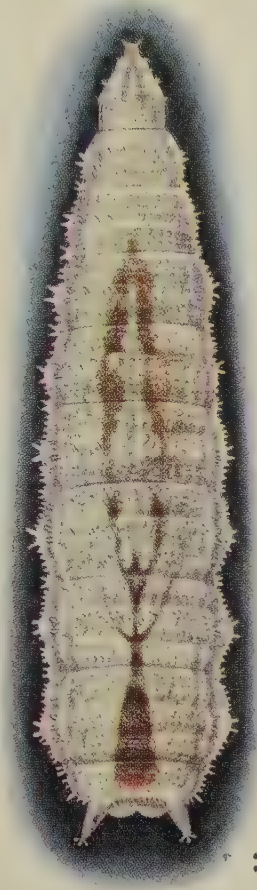
Fig. 6. The female fly (2·1 mm. × 0·66 mm.) (×26)

PLATE LVIII

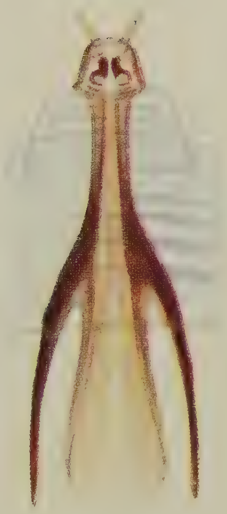


1

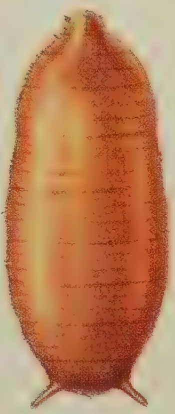
2



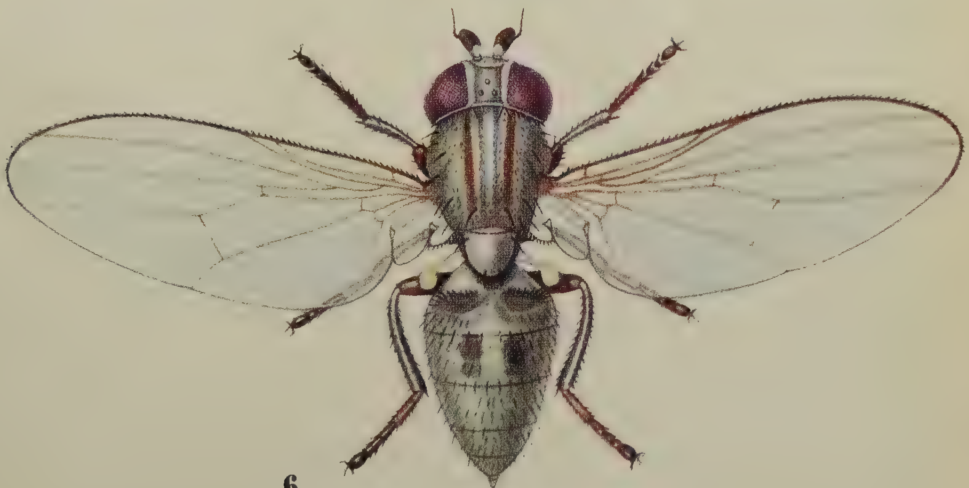
3



4



5



6

a small reticulation area near each pole. During hatching the chorion splits in the region of the narrow anterior pole and the young larva wriggles out of the egg-shell. The freshly hatched larva (Plate LVIII, fig. 2) measures 0·6×0·2 mm. It is flattened dorso-ventrally, broad in the posterior region and tapers gradually towards the head. It is white. The body segments are marked all over by fine tubercles, and a girdle of spines can be distinguished in the middle of each segment. The larva at this stage is metapneustic, the posterior spiracle opening on the last segment. The spiracles are pedunculate. The tracheal tube, passing through the short stalk of the spiracle, is bifurcated at the tip.

The larva moults three times, the first moult occurring within forty-eight hours after hatching. During moulting the skin ruptures longitudinally along the mid-dorsal line in the anterior region, developing a slit through which the larva wriggles out of its old skin. All the moulted skins are left on the leaf.

The full-grown larva (Plate LVIII, fig. 3) measures 4·0×1·0 mm. The lateral sides of various segments are rather fleshy and buldge out. They have deep fossae in the region of the abdomen, dividing the body into dorso-lateral and ventro-lateral regions. The small conical head and the thorax are ochraceous, while the rest of the body is yellowish brown, except in the mid-dorsal region, where it appears dark brown or even blackish, due to the coloured gut contents inside the body. The extensive and irregularly arranged fat body in the posterior region gives the larva general light yellowish appearance.

The head, three thoracic and eight abdominal segments can be easily distinguished, the last segment bearing dorso-laterally two well-developed peduncles of the posterior pair of spiracles and ventrally a pair of fleshy processes which are useful in the locomotion of the larva. The conical head (Plate LVIII, fig. 4) is small and retractile. The antennae are situated in the anterio-dorsal region. They are long and acicular, a rare feature in the cyclorrhapha larvæ. They are apparently composed of one segment only. The oral aperture is on the ventral side. The mouth-parts consist of :—(*i*) A pair of incurved mandibles which are broad at the bases and are well sclerotized, especially at the tips which are black ; (*ii*) a pair of maxillary palps which lie just above the mandibles ; (*iii*) two pairs of circular sucker-like organs which in other species of Chamaemyidae have been designated as ‘ sense organs ’. [Czerny, 1936]. The most conspicuous part in the anterior region of the larva is the pharyngeal sclerite which forms the floor of the head and extends up to the second thoracic segment. It is comparatively membraneous in the middle, the sides being highly chitinized and bifurcated posteriorly. At the level of the bases of the mandibles there is chitinous band all round the head.

Each of the body segments is divided by two light transverse furrow into three parts. The segmental spines and tubercles, which are minute in the freshly-hatched larva, are well developed now, the former being small and the latter truncated. The tubercles are present both on the dorsal and the ventral sides. They are irregular in arrangement, there being about six to eight or even ten rows on each side of a segment. There is a girdle of twenty spines in the middle of each segment, ten each in the dorsal and ventral portions, The full-grown larva is amphipneustic. The posterior spiracles are palmate and tripartite, their stalks being elongated, conical and well developed. The anterior spiracles are situated laterally in the hind region of the first segment. They resemble the posterior spiracles but their stalks are very short.

The larval period in December and January inside the laboratory having average maximum and minimum temperatures of 61·0°F. and 57·7°F. respectively was found to be sixteen to twenty-one days (average of ten observations).

When ready to pupate, the larva drops down on the ground where it pupates under fallen leaves or in the soil up to a depth of about one inch or so.

The larva exudes a blackish gummy substance before pupation and the pupae are found attached to the surface of the fallen leaves by this substance.

The puparium (Plate LVIII, fig. 5) measures 2·0 × 0·75 mm. It is reddish brown, elongated, oval in outline, flat on the ventral surface, somewhat convex dorsally and rounded at the posterior end. In the thoracic region there is a sudden depression and the head is drawn out or truncated. The tubercles and spines are reduced and the spiracles occupy the same positions as in the larva. The pupal period in December, January and February in the laboratory having average maximum and minimum temperatures of 62·7°F. and 57·8°F. respectively, varied between twenty-nine and forty-nine days.

The flies emerging from the cages lived on sugar solution in captivity from six to eight weeks. Without food they could live for two to four days only.

The fly.—The description of the fly (Plate LVIII, fig. 6) given by Czerny [1936] is reproduced below with slight changes :—

> Whitish gray. Head hemispherical, eyes oval, cheeks nearly one-fifth the length of the eyes, frons more than one-third the breadth of the head, almost parallel margined, with two broad black stripes. Antennae black, second segment with a white spot, the second joint about one-third of the third, antennal bristles black. Palps black, labella of the proboscis yellow. Mesonotum with two broad dark brown stripes reaching up to the scutellum and two small dark median stripes. Median stripes of the mesonotum with four rows of bristles along the sides. Scutellum brownish-black. Coxae black, femora black. Metatarsi yellow. Wings clear and shining. R 4 + 5 and M slightly converging towards the tip. Anterior cross-vein situated at about the hind third of the discoidal cell. Posterior cross-vein shorter than the distance between the two cross-veins. Squamae white, margined with medium-sized whitish hairs. Halteres pale yellow. Abdomen with two dark spots on the dorsal side of the third segment.
>
> Length 2·1 mm. ; breadth 0·66 mm.

SUMMARY

1. *Leucopis griseola* Fall. (Chamaemyidae : Diptera) is recorded for the first time in India.

2. This species is an important predator of *Aphis gossypii*, a bad pest of cotton at Delhi, its larvæ feeding actively on the young aphids. Several species of the genus *Leucopis* are known to be enemies of several aphids in other parts of the world.

3. The predator appears in the field in November and December. The small white eggs are generally laid by the fly in the afternoons between 3-30 and 5-0 P.M. During winter, inside the laboratory having average maximum and minimum temperatures of 61·0°F. and 57·7°F. respectively, the eggs hatch in four to seven days, the larval period is sixteen to twenty-one days, and the pupal period twenty-nine to forty-nine days. The larva undergoes three moults, the first moult occurring within about forty-eight hours of hatching. One larva can prey on seventy to one hundred nymphs. Pupation takes place on fallen leaves or in the soil. Newly emerged flies could be kept alive on sugar solution from six to eight weeks.

4. Besides *Aphis gossypii*, the predator larvæ have also been found at Delhi preying on *Macrosiphum granarium* (the barley and wheat aphid), *Myzus persicae* (infesting potato), and some unidentified aphids found on hollyhock, *palak*, mustard, etc.

ACKNOWLEDGMENTS

The authors have great pleasure in acknowledging the assistance rendered by Fieldman, Mr. Mohammad Shaffi, who was the first to notice the predator in the field, and helped us during our field and laboratory observations. Our thanks are also due to Mr. P. Narayanan, Artist, for so carefully preparing the plate depicting the life-history of the predator.

REFERENCES

Anonymous (1933). *Rept. Coucil Sci. Industr. Res. Aust.* 7, 26-31
———— (1935). *ibid.* 8, 16-23
———— (1936). *ibid.* 9, 28-34
Balch, R. E. (1934). *Sci. Agric.* 14, 374-383
Becker, Th. (1907). *Ann. Mus. Zoo. Ac. Sci.* 12, 309
Becker, Th. and Bezzi M. (1905). *Kat. Pal. Dipt.* 4, 236
Berger, E. W. (1918). *Qtrly. Bull. Florida Stat. Plant Board Gainesville* 2, 66-81
Bollow, (1917). *Deutsch. Ent. Zeitschr.* 173-174
Cherian, M. C. (1933). *Mad. Agric. J.* 11, 343-344
Curran C. H. (1934). 'North American Diptera', 365
Czerny, L. (1936). *Die Flieg. Pal. Reg.* 103, 4-13
Essig, E. O. (1913). *J. Ent. Zoo.* 5, 85-87
———— (1922). *ibid.* 14, 75-78
Fenton, F. A. (1917). *Canad. Ent.* 49, 309-320
James, H. C. (1934). *Stylops* 3, 105-107

Malloch, J. R. (1922). *Bull. Ill. State N. H. Surrey* **13**

———————— (1924). *Mem. Dept. Agric. Ind. (Ent. Ser.)* **8**, 67

———————— (1927). *Ann. M. N. H.* **19**, 575-577

Miller D. and Clark A. F. (1935). *N. Z. J. Sci. Tech.* **16**, 301-307

Perris, M. E. (1870). *Ann. Soc. Ent. France* **10**, 348-352

Smith, H. S. (1917). *Monthly Bull. Cal. Stat. Commiss. Hortic.* **6**, 108-144

——————— (1921). *Monthly Bull. Cal. Dept. Agric. Sacramento.* **10**, 570-597

Smith, R. H. (1923). *Idaho Agric. Expt. Stn. Bull.* **3**, 53-54

Smulyan, M. T. (1919). *Ann. Rept. Virginia, Poly. Inst. Expt. Stn.* 38-64

Tragardh, I. (1931). *Z. Angew. Ent.* **18**, 672-679

Vasilev, I. V. (1922). *Trans. 4th All-Russian Ent. Phytopath. Meeting*, 64-69

REVIEWS

Report of the Fourth International Grassland Congress, Great Britain, July 8th to 23rd, 1937. Available from the Joint Secretaries, Fourth International Grassland Congress, Aberystwyth, Wales. Pp. xxxiv + 486. Price £2.

In Europe, America, Canada and Australia the improvement in grassland is keeping pace with the improvement in dairy-cattle and live-stock. In comparison with other countries, India lags far behind in respect of both and the proceedings of the Grassland Congress reviewed below will indicate the extent to which progress has been made abroad and the up-hill task facing this country. In Europe the improvement of grasslands was thought of many decades back and the benefit of the work then commenced is being reaped after a lapse of half a century and more. In this country work on grasslands has just begun and the proposal to constitute a Fodder and Grazing Committee in every province is certainly the first step in the right direction in recognizing the national importance of undertaking grassland research and the great asset grasslands are to the nation.

The volume of the report comprising over 480 pages includes the presidential address delivered by Prof. R. G. Stapledon, report of the business meeting of the International Grassland Congress Association and papers read and discussed at the Congress. In all, sixty-nine papers were read at the Congress of which seventeen were in German.

Among other things the presidential address lays stress on the necessity of classification of grasslands to understand their inter-relations and for planning the work on definitely regional basis. Every grassland worth its name must include a legume as part of its herbage. At present sufficient exchange of legumes all over the world has not been undertaken and it would be necessary to do this in future to evolve suitable types for every country and provide proper conditions for their growth. In discussing the several factors affecting grasslands, the necessity of realizing the important rôle the animal plays in providing stock nitrogen without which improvement would well-nigh be impossible is prominently brought out. It is pointed out that it would be folly to permanently lay down lands as pastures or meadows, and that to bring them under the plough at regular intervals would pay in return many folds in the long run. The practice of repetition of treatment both in time and kind is strongly condemned and instead the rotation in time to avoid giving the same treatment at the same time of the year over and over again is rightly stressed. In order to provide nutritive grass at all and different times of the year the devising of suitable seed mixtures after sufficient trial is advocated.

Many of the points advocated in the presidential address are of greater applicability to temperate grasslands which have been subjected to investigations for many years. These suggestions are not of direct applicability to grasslands in sub-tropical and tropical countries where the conditions are entirely different and where investigations are required to be undertaken to arrive at what is suitable. But the broad principles stressed on, such as the introduction of legumes into grassland herbage, rotation in time, devising suitable seed mixtures, development of local strains in pasture herbage, are of universal applicability.

The papers read and discussed at the plenary session cover a wide range of aspects of grassland problems. A paper of interest is that on nutritive value of dried grass. Grass when young is at its most nutritive stage, and if dried and preserved it has the possibilities of replacing concentrates, such as oil-cakes and meals. The advantage of the dried grass is that it can be preserved for many years without its losing in its nutritive value. The information given on the elaborate organization set afoot to improve grasslands in the U. S. A., the aim and objects of the grassland investigators in that vast continent and the extensive work planned by the newly organized soil conservation service to restore many of the lands once given to pastures and grasslands, but now ruined due to excessive erosion, shows how seriously the work is viewed. It is something that even if copied on a much smaller scale by this country would be of immense benefit. Strain building in pasture herbage is of considerable importance and the contribution of the Welsh Plant Breeding Station in this direction is reflected in the number of new and valuable strains of pasture grasses and clovers evolved. The past achievements and future aims in grassland investigations in Sweden, species suitable for Canadian pastures and the characters of herbage plants suitable for hays and pastures form the subject matter of some of the papers. Viratanen of A. I. V. process fame discusses the practical advantages of associated growth of legumes. By growing a non-legume with a legume, the non-legume gets benefited because of the secretion of amino-acids into the soil by legumes. But the application of nitrates reduced this excretion.

In the section on grassland ecology papers contributed by workers from South Africa, United States of America and Hungary relate to the grasslands in their respective countries in regard to their present condition, the problems awaiting solution, the attempts made to improve them and the success achieved. In South Africa the shifting cultivations by the natives, the bringing under plough of vast areas of virgin land to meet the urban demand and the continuous depletion of the soil of its nutrition without in return putting back what is taken out of it have caused serious destruction of good land and have given rise to fresh problems requiring solution. The United States of America is endeavouring to restore depleted ranges on which depends a considerable portion of the nation's wool and mohair production. Sowing down of grasslands in the arid climates of Hungary and the effect of agricultural practices on the growth behaviour of pasture grasses are some of the other matters dealt with under this section.

The papers discussed before the section on seed mixture deal with the devising of suitable seed mixtures according to the purpose and use of the herbage and the type of land used for sowing. It is reported that white clover, when present in a seed mixture, exerts a good influence on the composition of pasture herbage, improves the protein contents of associated grass, increases the yield of the herbage greatly and makes seasonal production uniform.

In regard to seed rate for pastures the experience in New South Wales is that light seeding of pasture seed mixture is beneficial. Suitable seed mixtures for meadows and low moors and for poultry purposes form the subject matter of two papers. In the case of poultry it is observed that grass in poultry run serves three purposes ; it keeps the birds clean, provides vitamin and supplies protein. In India the poultry do not have sufficient run on grass and it would be worth while having grass plots where the poultry could be penned for purposes of exercise and feeding. For poultry use the turf recommended should consist of dense, dwarf sward which is hard wearing. Not more than 250 birds should be folded per acre as otherwise the grass will die out.

At the section on plant breeding, genetics and seed production, seven papers were read. The trend of many of the contribution to this section brings out the importance of strain building in evolving types suitable for pastures and meadows and types characterised by high seed production. The genetics of red clover from the point of view of its practical application is discussed. A knowledge of the linkage of some of the morphological characters with economic ones and the manner of inheritance of these characters aids considerably in combining the desired characters in a strain and in rapidly evolving new and desirable types. The methods of breeding grassland plants, the work on breeding of grasses in Rumania, how to grow pasture-types of grasses for seed and methods of harvesting clover and grass seeds make up the rest of the contribution to this section.

The fertilizer section deals with the importance of manuring pastures and meadows with artificials. The practice of manuring grasslands in Europe is on a par with that of manuring cereals, root and other crops and the importance of this practice may not be readily understood in this country where even cash crops are not adequately manured. In India manuring of grasslands is not yet a practical proposition but a time may come when after the restoration of many of the derelict and over-grazed lands manuring would be necessary. In Great Britain it is found that the supplying of lime and phosphate to grasslands deficient in these minerals is a necessity since many of them suffer from such deficiency. It is shown from experiments conducted in the arid regions of Hungary that by means of manurial treatment alone no material improvement can be made in the grasslands of these parts. What is of greater importance is the aeration of soil, deeper crumb and storage of the winter moisture. For the arid regions temporary lays are more suited than permanent pastures. The rôle of potash on the protein content and nitrogenous fertilizer on the botanical composition of pastures are other subjects discussed under the subject of fertilizers.

The section dealing with the nutritive value of pastures and fodder conservation had for its consideration the nutritional aspect of forage production in Canada where it is shown that concentrates to the value of $35,000,000 are purchased annually from the western grain regions where they are produced at low cost for the east which constitutes the main area of dairy and live-stock production. This is the cause of increase in the cost of dairy and live-stock products. It is shown that the more rational use of the forage available during the five months and the developing of better quality winter roughages richer in protein, minerals and vitamins would help in producing dairy and live-stock products at low cost in eastern Canada. From the point of view of nutritive values manuring of pastures produces two effects, the direct which improves the protein, phosphoric acid and other mineral contents of the herbage and the indirect which brings about a change in the botanical composition of the herbage. Some times the direct effect is masked by the indirect as, when nitrogenous fertilizers are applied, there is a reduction in the population of leguminous plants which are rich in protein. The artificial drying of grass to which reference has been made earlier and which is assuming more and more importance in Great Britain is dealt with from the economic aspect. It is shown that although the cost of production was higher than anticipated, likewise the selling value of the products was also higher. It appears that in a country like Great Britain having prolonged wet season and where the conservation of fodder in good condition is of utmost importance grass drying has great practical applicability. From the progress made within a few years, there is every probability of reducing the cost of production so that it will be within the means of great many farmers to adopt it in the future.

In India, as in the case of manuring grasslands so with grass drying there is little prospect of its application at present because of the prohibitive cost. In many respects this country is agriculturally far behind others and yet a time may come when what would appear to be impracticable at present may become quite necessary much later. The question of the production of ensilage has passed beyond the initial stages and now much attention is devoted to the addition of mineral acids, molasses, etc., to it and study the effect on the metabolism of animals fed with ensilage so prepared. The losses involved in the conservation of fodder is a question of great importance to countries in Europe where for nearly two thirds of the year fresh fodder is not available. So the determination of the causes of losses is a necessity in avoiding such losses. This subject is discussed.

The section on management, yield and economic aspects of pastures is necessarily of much importance. Unless it pays, the maintenance of pastures is not advisable and to make pastures pay, proper management is of utmost importance and good management necessarily means good yield both in products and cash. Seven years' trials conducted on monthly clippings of pastures in America have indicated that protein, moisture, calcium, and, to a less extent, phosphoric acid contents decrease with advancing season. Another interesting fact that has emerged from these trials is that samples of vegetation representing the same growth period were quite similar in chemical analyses, regardless of genera, family, or fertilizer used.

The principles established by botanist and chemist for proper management should be further developed by economist to show the monetary advantage of following clearly defined methods in pasture improvement. The association of economists with botanists and chemists in restoring grasslands to a state of reaping good returns is beginning to be realized.

The report as a whole forms very interesting reading and is highly informative. It would be of much use to grassland investigators in all countries as it includes reports of experiments conducted in different parts of the world and many aspects of grassland improvement. [L. S. S. K.]

The frameworking of fruit trees. By R. J. Garner, and W. F. Walker, (Imperial Bureau of Horticulture and Plantation Crops Occasional Paper, No. 5, 1938). Available from the Deputy Director, Imperial Bureau of Horticulture and Plantation Crops, East Malling Research Station, East Malling, Kent, England.
Pp. 19, bibl. 26. Price 1*s*.

The authors set out briefly, but intelligibly, the results of practical orchard experiments in Tasmania, England and elsewhere, on methods of topworking and thereby changing the variety of fruit trees at will.

The method commonly accepted in the past has consisted—to put it somewhat crudely—in chopping off the top of the tree and inserting one or two grafts into the stump, or into not more than the two or three branches which remain.

The method which they describe consists essentially in the insertion of a very large number of grafts right out at the ends of all the smallest branches.

The labour involved is very much greater but the return of the tree to productivity is also greatly accelerated and would appear to make the practice worth while.

Four ways of carrying out the operation are described, namely, stub-grafting, side-grafting, inverted L bark-grafting and awl-grafting. Clear line drawings greatly facilitate an understanding of the methods, while photographs showing an apple tree immediately after treatment and another similar tree two years after treatment bearing five bushels of fruit, demonstrate the results which can be expected.

Possible difficulties, choice of grafting wax, costs and other practical points are all fully discussed.

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Periodical Abstracts

Lists of publications and papers on Soil Science published in the Empire Overseas in—

	Price	
	s.	*d.*
1933	1	0
1934	1	0
Soil Research in the British Empire published during 1935	1	0
Soils and Fertilisers (continuation of Publications relating to Soils and Fertilizers), Vol. I (1938), No. 1—		
Issued six times yearly. Subscription rate per annum	20	0

Occasional Papers

Technical Communications—		
35. Design and analysis of factorial experiments. By F. Yates	5	0
36. Erosion and soil conservation	5	0
Annual Report: For the year 1934-35	0	6
,, ,, ,, 1936-37 (8th report)	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions (by the late Sir J. B. Harrison)	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1934-37	25	0

II. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL HEALTH, VETERINARY RESEARCH LABORATORY, NEW HAW, WEYBRIDGE, SURREY

Abstracting Journal

The Veterinary Bulletin—		
1931. Vol. 1. Quarterly (1st Number, April)	7	6
Annual subscription	20	0
Subsequent volumes. Monthly (1st Number, January)	5	0
Annual subscription (postage paid) (Vol. 8 current)	40	0

Indexing Publication

	Price	
	s.	d.
Index Veterinarius—Four issues a year. First issue April 1933— Annual subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed (Vol. 6 current)	100	0

III. Obtainable from the Imperial Bureau of Animal Nutrition, Rowett Research Institute, Bucksburn, Aberdeen

Journal

Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)—		
Subscription per volume of 4 numbers (Vol. 8 current)	42	0
Per single number	13	0

Occasional Papers

Technical Communications—		
8. Nutrition Research in the British Colonial Empire	1	0
9. Methods for Chemical Analysis of Biological Material in Nutrition Investigations	1	0
Occasional Communications—		
2. Etiology of Endemic Goitre.		

IV. Obtainable from the Imperial Bureau of Plant Breeding and Genetics, Plant Breeding Institute, School of Agriculture, Cambridge

Journal

Plant Breeding Abstracts—		
Quarterly. Annual subscription (Vol. 8 current)	15	0
Single copies	5	0

Occasional Papers

Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
,, ,, ,, Vol. VI and Vols. VI-VII, each	2	6
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932-1935. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication of the Imperial Bureaux of Plant Genetics)	10	0
Bibliographical Monographs—		
South American Potatoes and their Breeding Value	3	6
Tobacco Breeding Bibliography	1	0

V. Obtainable from the Imperial Bureau of Pastures and Forage Crops, Welsh Plant Breeding Station, Agricultural Buildings, Alexandra Road, Aberystwyth, Wales

Journals

	Price s.	d.
Herbage Abstracts—		
Quarterly. Annual subscription (Vol. 8 current)	15	0
Single numbers	5	0
Herbage Reviews—		
Subscription is at present included in the Herbage Abstracts (Vol. 6 current)		

Occasional Papers

	s.	d.
Bulletins—		
25. Erosion and soil conservation. By G. V. Jacks and R. O. Whyte	5	0

VI. Obtainable from the Imperial Bureau of Horticulture and Plantation Crops, East Malling Research Station, East Malling, Kent

Journal

	s.	d.
Horticultural Abstracts—		
A quarterly abstract publication of current horticultural literature—		
Annual subscription (Vol. 8 current)	15	0
Single copy	4	0

Technical Communications

	s.	d.
9. Review of the Literature on Stock-scion Incompatability in Fruit Trees, with particular reference to Pome and Stone Fruits. G. K. Argles	5	0

Occasional Papers

	s.	d.
5. The Frameworking of Fruit Trees. R. J. Garner and W. F. Walker, 1938	1	0
Other Publications—		
Index to Volumes I—X of the *Journal of Pomology and Horticultural Science*, 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science*. Available from the Bureau	5	0
Old and New Standpoints on Senile Degeneration, 1931. By A. P. C. Bijhouwer	0	6

VII Obtainable from the Imperial Bureau of Animal Breeding and Genetics, Institute of Animal Genetics, University of Edinburgh, King's Buildings, West Mains Road, Edinburgh

Journal

	s.	d.
Animal Breeding Abstracts (Quarterly). Commencing April, 1933. Annual subscription (Vol. 6 current)	15	0

Occasional Papers

	Price s.	Price d.
Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0

VIII. OBTAINABLE FROM THE IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY (HELMINTHOLOGY), INSTITUTE OF AGRICULTURAL PARASITOLOGY, WINCHES FARM DRIVE, HATFIELD ROAD, ST. ALBANS, HERTS

Journals

	s.	d.
Bibliography of Helminthology. For the year 1933—		
Library edition, bound in cloth	10	6
Stiff paper cover only	8	0
(From 1934 incorporated with Helminthological Abstracts)		
Helminthological Abstracts. (Issued in five or six parts per volume, each volume covering the literature of a single year.) Subscription per volume, payable in advance	30	0
Completed volumes bound in cloth	32	0

Occasional Papers

	s.	d.
Helminth Parasites of New Zealand. By M. R. Young	4	0
Notes and Memoranda—		
11. Recent Developments in the Control of *Heterodera marioni*. 6 pp.	1	6

PUBLICATIONS ISSUED BY THE IMPERIAL INSTITUTE OF ENTOMOLOGY, 41, QUEEN'S GATE, LONDON, S. W. 7

	s.	d.
Bulletin of Entomological Research.—Published quarterly and containing original articles on Economic Entomology. Issued post-free. Annual subscription (payable in advance) (Vol. 28 current)	30	0
Review of Applied Entomology.—Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series. Series 'A' dealing with insect and other arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin, Series 'B' dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post-free. (Vol. 26 current).		
Annual subscription (payable in advance)	30	15
Vol. XXIII (1935) onward	42	21

	Series 'A' *s.* Price	Series 'B' *s.* Price

	s.	*d.*
Zoological Record—Part Insecta.—Published annually about July in each year and containing as complete a record as possible of the literature of the previous year chiefly from the systematic standpoint.		
Annual subscription (including postage)	15	6
Report of the Fourth Imperial Entomological Conference, 19-27th September 1935	4	0
Biological control of an Insect in Fiji. An account of the Coconut-leaf Mining Beetle and its Parasite Complex. By T. H. C. Taylor	12	0

Publications obtainable from the Imperial Mycological Institute, Kew, Surrey

Journal

Review of Applied Mycology.—Annual subscription, 12 monthly parts, with title page and index (post-free)	21	0
Single part	2	0
Title page and index	3	0
Report on the Third Imperial Mycological Conference, 1934	2	0
Annotated account of fungi received at the Imperial Mycological Institute. List II. Fasc. 1. By E. W. Mason	1	0
Annotated account of fungi received at the Imperial Mycological Institute. List II, Fasc. 2. By E. W. Mason	2	0
Annotated account of fungi received at the Imperial Mycological Institute. List II, Fasc. 3. By E. W. Mason	1	0
A list of Mycologists resident in the British Empire, 1938. 5th Edn. January 1938	1	0

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian Postage]

1. Agriculture and Live-stock in India

ICAR. 1. A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the Tropics. (Established 1931. Published in January, March, May, July, September and November. Prepayable subscription Rs. 6 or 9*s*. 9*d*. per annum. Price per part Rs. 2 or 3*s*. 6*d*.) Volumes I to VII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5. A bi-monthly scientific journal of agriculture and the allied sciences mainly devoted to the publication of the results of original research and field experiments. (Established 1931. Published in February, April, June, August, October and December. Prepayable subscription Rs. 15 or 24*s*. per annum. Price per part Rs. 3 or 5*s*. 3*d*.) Volumes I to VII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6. A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931. Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s*. 9*d*. Price per part Rs. 2 or 3*s*. 6*d*.) Volumes I to VII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10·1 No. 1. The Fungi of India, By E. J. Butler, C.I.E., D.Sc., M.B., F.R.S., and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s*.

ICAR. 10·2 No. 2. Life-histories of Indian Microlepidoptera, Second Series: Alucitidæ (*Pterophoridæ*, Tortricina and Gelechiadæ), By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s*. 6*d*.

ICAR. 10·3 No. 3. The Open Pan System of White-Sugar Manufacture, By R. C. Srivastava, B.Sc. (1935, 2nd edition.) Price Rs. 3-2-0 or 5*s*. 6*d*.

ICAR. 10·4 No. 4. Life-histories of Indian Microlepidoptera; Cosmopterygidæ to Neopseustidæ, By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1933). Price Rs. 4-8-0 or 7*s*. 6*d*.

ICAR. 10·5 No. 5. The Bombay Grasses, By E. J. Blatter, S.J., Ph.D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. (1935). Price Rs. 20-12-0 or 32*s*. 6*d*.

ICAR. 10·6 No. 6. Helminth Parasites of the Domesticated Animals in India, By G. D. Bhalerao, M.Sc. (1935). Price Rs. 7-12-0 or 13*s*. 3*d*.

ICAR. 10·7	No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng. and the Isolation of Types Resistant to the Disease, By W. McRae M.A., D.Sc. (Edin.), F.L.S. and F.J.F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s*. 3*d*.
ICAR. 10·8	No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy, By C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s*. 9*d*.
ICAR. 10·9	No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah-Shell Oil Storage and Distributing Company of India, Ltd., By C. P. G. Wade. (1935). Price Rs. 3-14-0 or 6*s*. 6*d*.
ICAR. 10·10	No. 10. The Spotted Bollworms of Cotton in South Gujarat, By B. P. Deshpande and N. T. Nadkarny, B.Ag. (1936). Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 10·11	No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus muscles and the formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations, By. H. N. Chelva Ayyangar, G.M.V.C. (1937). Price Rs. 4-10-0 or 7*s*. 9*d*.
ICAR. 10·12	No. 12. The Fungi of India, Supplement I. By B. B. Mundkur. Price Re. 1-6-0 or 2*s*. 3*d*.

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8·1	No. 1. List of Publications on Indian Entomology, 1930, By the Imperial Entomologist, Pusa. (1934). Price As. 14 or 1*s*. 6*d*.
ICAR. 8·2	No. 2. List of Publications on Indian Entomology, 1931, By the Imperial Entomologist, Pusa. (1934). Price As. 8 or 10*d*.
ICAR. 8·3	No. 3. List of Publications on Indian Entomology, 1932, By the Imperial Entomologist, Pusa. (1934). Price As. 12 or 1*s*. 3*d*.
ICAR. 8·4	No. 4. Host Plant Index of Indo-Ceylonese Coccidae, By S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. (1934). Price Re. 1-10-0 or 2*s*. 9*d*.
ICAR. 8·5	No. 5. List of Publications on Indian Entomology, 1933, compiled by the Imperial Entomologist, Pusa. (1935). Price As. 9 or 1*s*.
ICAR. 8·6	No. 6. Bee-keeping, By C. C. Ghosh, B.A., F.E.S. (3rd Edition.) (1936). Price Re. 1-14-0 or 3*s*. 3*d*. (out of stock)
ICAR. 8·7	No. 7. List of Publications on Indian Entomology, 1934, compiled by the Imperial Entomologist, Pusa. (1935). Price Re. 1-2-0 or 2*s*.
ICAR. 8·8	No. 8. Selected Clinical Articles, Part I, By G. K. Sharma, G.P.V.C. and R. L. Kaura, B.V.Sc., M.R.C.V.S. (1936). Price As. 8 or 10*d*.
ICAR. 8·9	No. 9. Statistical Methods and their Application to Agronomy; A bibliography, By. K. K. Guha Roy. (1936). Price Rs. 2-2-0 or 4*s*.
ICAR. 8·10	No. 10. Diseases of Sugarcane and Methods for their Control, By L. S. Subramaniam. (1936). Price Re. 1-14-0 or 3*s*. 3*d*.
ICAR. 8·11	No. 11. Tables of Standard Errors of Mendelian Ratios, compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell) and P. Krishna Rao, L.Ag. (1936). Price As. 12 or 1s. 3*d*.
ICAR. 8·12	No. 12. List of Publications on the Botany of Indian Crops, Part II, for the period 1928-32, By R. D. Bose. (1936). Price Rs. 3-6-0 or 6*s*. 9*d*.

ICAR. 8·13	No. 13. Two New Statistical Tables based upon Fisher's '*t*', By M. Vaidyanathan. (1936). Price As. 6 or 8*d*.
ICAR. 8·14	No. 14. List of Publications on Indian Entomology (1935), compiled by the Imperial Entomologist Pusa. (1937). Price Re. 1-4-0 or 2*s*.
ICAR. 8·15	No. 15. Selected Clinical Articles, Part II, By G. K. Sharma, G.P.V.C. R. L. Kaura, B.V.Sc., M.R.C.V.S., S. Ganapathy Iyer, G.M.V.C., G. S. Khan, B.Sc. and S. Mangrulkar, M.Sc., M.R.C.V.S., D.T.V.M. (Edn.) (1937). Price Re. 1-4-0 or 2*s*.
ICAR. 8·16	No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders, by P. E. Lander, M.A., D.Sc., F.I.C., I.A.S. (1937). Price Rs. 3-14 or 6*s*. 9*d*.
ICAR. 8·17	No. 17. A Brief Survey of some of the Important Breeds of Cattle in India, by Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S., F.N.I. (1938). Price Rs. 2 or 3*s*. 6*d*.
ICAR. 8·18	No. 18. Milk Records of Cattle in Approved Dairy Farms in India, by K. P. R. Kartha, B. A. (*In the Press.*)
ICAR. 8·19	No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province, by Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.) F.N.I. and H. N. Batra, B.Sc., Assoc. I. A. R.I. Price Re. 1 or 1*s*. 9*d*.
ICAR. 8·20.	No. 20. Report on an Enquiry into the Cultivation of Cloves in India, By A. K. Yegna Narayan Aiyar. Price Rs. 2-4-0 or 3*s*. 9*d*.
ICAR. 8·21	No. 21. Investigations on the Cold Storage of Mangoes, By G. S. Cheema, D.Sc., I.A.S., D. V. Karmarkar, M.Sc., Ph.D., A.I.I.Sc. and B. M. Joshi, M.Sc. (*In Press*)

6. Annual Reports of the Imperial Council of Agricultural Research

ICAR. 12·31	Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.
ICAR. 12·32	Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.
ICAR. 12·33	Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of stock.)
ICAR. 12·34	Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Re. 1-8-0 or 2*s*. 6*d*.
ICAR. 12·35	Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.
ICAR. 12·36	Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.
ICAR. 12·37	Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Re. 1-2-0 or 2*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9·29	Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock.)
ICAR. 9·31	Review of Agricultural Operations in India, 1929-31. Price Rs. 5 or 8*s*. 3*d*.
ICAR. 9·33	Review of Agricultural Operations in India, 1931-33, Price Rs. 5-12-0 or 9*s*. 6*d*.

	Agriculture and Animal Husbandry in India, 1933-34 and 1934-35—
ICAR. 13-1-35	Part I.—Crop Production. Price Rs. 4-14-0 or 8*s.*
ICAR. 13-2-35	Part II.—Animal Husbandry. Price Re. 1 or 1*s.* 9*d.*
ICAR. 13·36	Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10 or 7*s.* 9*d.*

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2	Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s.* 6*d.*
ICAR. 2. 2	Proceedings of the Second Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at Madras from the 14th to the 16th December 1936, with Appeddices. Price Rs. 3-10-0 or 6*s.* 3*d.*
ICAR. 3	Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s.* 9*d.*

9. Miscellaneous

VRI. 1	A Description of the Imperial Institute of Veterinary Research, Muktesar and its Sub-station, the Imperial Veterinary Serum Institute, Izatnagar, By F. Ware, F.R.C.V.S. Price Re. 1-4-0 or 2*s.*
ARI. 7. 187	The Production of Cigarette Tobacco by Flue-curing, By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. and Kashi Ram. *Imp. Inst. Agri. Res., Pusa Bull.* No. 187. Reprinted (1935). Price Re. 1 or 1*s.* 9*d.*
ICAR. 16	A Handbook of Statistics for Use in Plant Breeding and Agricultural Problems, By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s.* 3*d.*
ICAR. 7	Report on the Work of the Imperial Council of Agricultural Research in Applying Sciences to Crop Production in India, By Sir John Russell, D.Sc., F.R.S. Price Re. 1-14 or 3*s.* 3*d.*
ICAR. 18	Report on the Development of the Cattle and Dairy Industries of India, By Norman C. Wright, M.A., D.Sc., Ph.D. Price Re. 1-8-0 or 2*s.* 6*d.*

Copies of the above publications can be had from :—

The Manager of Publications, Civil Lines, Delhi and from any of the Agents, a list of whom will be found on the inside page of the front cover.

Purchasers not residing in Asia, Africa and Australia should apply to the High Commissioner for India, India House, Aldwych, London. Prices include Indian postage and packing.

Note.—When indenting please give only the symbol preceding the name of the publication.

GIPD—S3—262 IC of AR—17-10-38—800.

ORIGINAL ARTICLES

STUDIES IN PLANT BREEDING TECHNIQUE

IV. THE INHERITANCE OF AGRICULTURAL CHARACTERS IN THREE INTER-STRAIN CROSSES IN COTTON

BY

J. B. HUTCHINSON

V. G. PANSE

AND

G. K. GOVANDE

Institute of Plant Industry, Indore, Central India

(Received for publication on 4th February 1938)

CONTENTS

		PAGE
I.	INTRODUCTION	757
II.	EXPERIMENTAL DESIGN	758
III.	ANALYSES OF VARIANCE	759
IV.	WITHIN-PLOT VARIANCE	762
V.	DISCUSSION	763
VI.	SUMMARY	766
VII.	ACKNOWLEDGMENTS	767
	REFERENCES	767

I. INTRODUCTION

THE work here reported was initiated in 1930 by Mr. F. K. Jackson, then Director of the Institute of Plant Industry, as a contribution to the solution of the problem of the inheritance of staple length and ginning percentage in Indian cottons. The first experiments were carried out by Mr. Kubersingh, then Plant Breeding Assistant. Selections for high staple length and ginning percentage were made in F_2's of crosses between Bani, Malvi and C 520, and were sown in 1933. Examination of the F_2 data and F_3 progenies convinced the senior author that the plant-breeding approach held out no hope of success. The introduction of selection in the F_2 precluded a genetic study of the problem and, in the absence of selections for low staple length and ginning percentage, provided no evidence on the magnitude of the genetic differences involved.

In 1933 the experiment was redesigned, and the plant breeding element omitted. The same three strains, Malvi, Bani and C 520 were used. All three are strains of *G. arboreum* var. *neglectum* [Hutchinson and Ghose, 1937,2]. C 520 is a strain of United Provinces Bengals bred by the Economic Botanist

(Cotton), United Provinces Government, and belongs to forma *bengalensis*. Bani belongs to forma *indica*. The strain used was obtained from the Economic Botanist (Cotton), Central Provinces, Nagpur. Malvi is somewhat intermediate in character between formas *bengalensis* and *indica*, and occupies a tract to the north of the area of the old, medium-staple types of *indica*, but one where the invasion of *bengalensis* appears to have been of small importance [Hutchinson and Ghose, 1937,1]. Its relationships are therefore rather obscure. The strain used in the experiment was Malvi 8, somewhat coarser in staple and higher in ginning than typical Malvi.

All three strains were self-fertilised and line-bred at Indore for seven generations before the experiment started. Crosses were made in 1933, and F_1's grown in 1934. In 1935 parents, F_1's and F_2's were grown together in one experiment.

II. Experimental design

It was decided to use a randomised progeny row design [Hutchinson and Panse, 1937] for the experiment in order to facilitate comparison between generations and to reduce, by the elimination of block effects, the environmental contribution to the variance between plants.

The experiment was laid out in ten randomised blocks, each block containing eighteen plots. Germination was recorded on all blocks, but for all other observations one block was discarded on account of great variation in fertility. The plots were made up as follows :—

Generation	Number	Total
Parents . . .	One of each	3
F_1's	One of each	3
F_2's	Four of each cross	12

Each plot consisted of a single row of 20 holes, one ft. apart. Rows were 2 ft. apart. Two non-experimental rows were sown all round each block with seed of the same material.

Plant breeding experiments at Indore are normally sown with three seeds per hole, and are subsequently thinned, only the strongest seedling being left at each point. In order to avoid any possibility of selection which might introduce a bias into data collected later in the experiment, only a single seed was sown at each point, and no thinning was done. It is doubtful whether the gain is commensurate with the loss of precision from irregularity in stand.

The provision of sufficient seed of parents and F_1's was rather difficult. Of Malvi, it was necessary to sow seed from three sister plants, and of Bani, seed from two sister plants. Sufficient seed of C 520 was available from a single plant. In making the crosses to provide seed for the F_1, flowering was never sufficiently rapid to allow of the use of one pair of plants only as would have been the ideal arrangement, and flowers of any sib were used as they were available. Actually each F_1 plot had to be sown with a different cross, one or both parents being different in every case. It was considered that the differences between the three strains were so large compared with any genetic differences between sibs of the same strain, that the latter could be ignored. Reference to Tables VII-X shows that in one character out of the four examined, Malvi, of which three sibs were included, had a lower within-plot variance than the other two parents and in two characters, Bani, of which two sibs were included, had a lower within-plot variance than C 520. It appears that the inclusion of progenies of more than one plant has not consistently increased the variance of within-plots.

Records were taken of germination, number of the node at which the first fruiting branch appeared (node number), yield of *kapas*, staple length (halo-length in mm.), and ginning percentage. Analyses of variance of plot values were carried out on all characters. Plot totals were used for germination, and plot totals adjusted for final stand by the analysis of covariance, for *kapas* yield. For node number, staple length and ginning percentage, plot means were used. Within-plot variances were calculated for all characters except germination.

III. ANALYSES OF VARIANCE

The analysis of variance was carried out for each cross separately. This procedure was preferred to a combined analysis of all the data in order to employ the appropriate error variance for comparisons in each cross owing to the possibility of this being different in the different crosses. Reference to Tables I to V would show that there are appreciable differences in the residual variance in the three crosses. Also, comparisons within each cross are of greater interest than average comparisons over the three crosses. The number of degrees of freedom for error is still sufficiently large for the separate analyses and hence no serious loss of precision need be expected. The analyses are summarised in Tables I-V. The information obtainable from the analyses falls under the following heads :—

Differences between parents.

Differences between generations (heterosis).

Differences between F_2's from sister F_1 plants (due to heterozygosis of one or both parents).

Differences between parents.—In staple length Bani exceeded the other two by 2 mm., which was a significant difference. Malvi and C 520 were not significantly different. In ginning percentage C 520 exceeded Malvi by 4 per cent and Malvi exceeded Bani by 5 per cent, both differences being significant. In adjusted yield Malvi was slightly but significantly better than Bani, and both were significantly better than C 520, which they exceeded by about 100 grms. and 60 grms. per plot, respectively. In node number Malvi exceeded C 520 by 0·74, and C 520 exceeded Bani by 0·47, both differences being significant. In germination Bani exceeded Malvi by 2·8 seedlings per plot, a significant amount, but Malvi exceeded C 520 by only 0·7, which was not significant.

Differences between generations.—In Tables I-V the mean of all four F_2 families in each cross is given in the comparison between generations, and the means of the individual families are compared separately. Differences between sister F_2 progenies are discussed below, and only the mean of all F_2's per cross is considered here. In staple length, ginning percentage, and yield of *kapas,* the F_1 exceeded the mean of the parents* by significant amounts in every cross, even when the parents did not differ significantly. In germination, the F_1 exceeded the mean of the parents in all cases, but significantly only in Malvi × C 520. In node number, the F_1 was significantly lower than the mean of the parents except in Bani × C 520 where the difference was not significant. In most cases, as would be expected, the mean of the F_2 was intermediate between the F_1 and the mean of the parents. Exceptions occurred in staple length, where in the two Bani crosses the F_2 exceeded the F_1 slightly, but not significantly, node number, where in the Bani × C 520 cross the F_2 exceeded the mean of the parents by a significant amount, and in germination, where the F_2 was slightly, but not significantly, below the mean of the parents in the two Bani crosses. In all, save one, of the exceptional crosses, there were significant differences between F_2 progenies, and as only four F_2 progenies were grown in each cross, the variances of the means of these F_2's would be large, and values transgressing the limits of the F_1 or the mean of the parents, of frequent occurrence.

Plant-breeding work in cotton is based on self-fertilisation and the isolation of homozygous lines. No difficulty has arisen from loss of vigour on selfing, and heterosis has only been recorded in interspecific crosses. It was not expected, therefore, that evidence of heterosis would be obtained in the present experiment, which involves inter-varietal hybrids only. Heterosis proved to be large and important, however, in all characters studied except germination. Even in the cross between the two higher yielding strains, the F_1 outyielded the higher yielding parent by about 20 per cent. Further, the dominance bias is in all cases in the direction in which recent selection has operated, as predicted by Fisher *et al.* [1932]. In staple length, ginning percentage, yield, and germination, this is the same as if dominance were due to greater vigour of the heterozygote, but in node number, where the development of the modern annual cottons has been achieved by reduction of the node number by selection [Hutchinson, 1937], low is dominant over high, which is the reverse of what would be expected if dominance were due to heterozygote vigour.

Dominance in the above paragraphs has been used in the general sense that the F_1 resembles one parent more closely than the other. Similar results can, however, be obtained without assuming dominance (in its strict sense that the heterozygote of any factor pair resembles one of the homozygotes more closely than the other) as arising from a non-additive interaction between factors whereby the effect of any factor on a particular character is dependent on the other factors present. Fisher [1918] uses the term 'epistasy' for this type of factor interaction and is of opinion [Fisher, 1931] that the selective forces giving rise to dominance in factors of large individual effect may, in quantitative characters, give rise to a condition where one gene has more than half the effect of two whether they are at the same or different loci.

---

* It should be noted that the proper comparison for the estimation of heterosis is between the F_1 and the mean of the parents, and not between the F_1 and the parent showing dominance.

It is possible to build up various non-additive systems of gene interaction [Rasmusson, 1933] producing effects similar to those due to dominance in F_1 and later generations. The limiting condition is that in which the maximum effect is produced by a single gene and this is illustrated in a simple form by duplicate factors with complete dominance. It will be seen that in quantitative characters effects of epistasy and dominance are very similar, and it appears that the only way of distinguishing the two is by a comparison of F_2's with back-crosses. True dominance will cause no asymmetry in the back-cross distribution. This point could not be studied here since back-cross progenies were not included in the present experiment. It has been shown, however, [Hutchinson, 1936] that in node number with no evidence of asymmetry in the parental types the skewness observed in F_2 persists in the back-cross, leading to the conclusion that node number genes are probably geometric rather than additive in their effect.

Differences between F_2's from sister F_1 plants.—Significant differences between F_2 progenies occurred in the Bani crosses in staple length, Malvi × C 520 in *kapas* yield, the Bani crosses in node number, and the Malvi crosses in germination. As all three parents had been selfed for seven generations, the extent of heterozygosity in them is surprising.

Two important considerations arise from the demonstration of heterogeneity among F_2 progenies. The first is that so long as genetic variance exists among parents, it will occur also in their F_1 progenies, and it is impossible to estimate the genetic variance in F_2 by subtracting from the within F_2 variance, an estimate of the environmental variance derived from the F_1. The second consideration concerns the effect of selection. Direct selection has been exercised on the three parental types for staple length, ginning percentage and *kapas* yield. No direct selection has been practised for node number or germination during line breeding, though both characters are subject to natural selection. Inspection of Tables I-V shows that the differences between sister F_2's are on the whole much greater in characters not subject to direct selection than in those which were under selection. The effect of selection on variance may be studied statistically by comparing z for F_2 progenies *v.* error for the selected and unselected characters. The relevant values of z are given below :—

	Malvi × Bani	Malvi × C 520	Bani × C 520
Staple length . .	+0·704	—1·080	+0·668
Ginning percentage .	—0·331	+0·054	+0·444
Kapas yield . . .	+0·294	+0·618	—0·660
Node number . .	+0·898	+0·476	+1·268
Germination . . .	+0·822	+0·464	+0·076

There were four large positive values of z out of nine in the selected characters, and five out of six in the unselected. This result is in agreement with expectation, since Fisher [1922] has shown that selection is far more powerful in reducing genetic variance than random extinction of genes. Extensive data would be required to provide a critical test of the validity of this conclusion with the rapid random extinction occurring with selfing and line breeding, but so far as the present data go, it appears to hold good.

IV. WITHIN-PLOT VARIANCE

An attempt was made to study the genetic variance resulting from crossing by studying the within-plot variances of the three generations. Data are summarised in Tables VI-X.

For staple length, two calculations were made. In Table VI are given the variances obtained by treating each generation as a simple frequency array, and making no allowance for block differences. In Table VII are given variances obtained after making an adjustment for block differences. As the number of plants per plot varied from twenty downwards according to accidents of germination and subsequent survival, a straightforward elimination of the block effect by the analysis of variance was not possible. Accordingly, correction factors were calculated from the ratio $\frac{\text{grand mean for the whole experiment}}{\text{block mean for all crosses}}$ for each block, and sums of squares were calculated from corrected single plant values. Actually, the crude single plant values were squared, and the sum of squares for each block multiplied by the square of the correction factor for that block, and an adjusted variance built up. For ginning percentage, *kapas* yield, and node number, adjusted variances only are given (Tables VIII-X). For each cross in each Table a ' within parents ' variance was calculated for comparison. This was obtained by summing the within-plots sums of squares of the two parents of the particular cross, and dividing by the sum of the degrees of freedom.

In the above method of calculating the variance the whole data of a progeny have been treated as a single array and a correction applied for block differences. An alternative method is to treat the data of the several replicates of a progeny as separate arrays, calculate the variance within each array and then pool it over the different arrays. In so doing, however, variance between replicates will be entirely lost and a part of this may be genetic.

Comparison of Tables VI and VII shows the extent to which environmental variation can be eliminated by adjustment for blocks. The percentage reduction on adjustment (Table VII, last column) varied from 15 to 31.

Considering Table VII only, in all crosses the variance of the F_2 exceeded that of the F_1, significantly so in the C 520 crosses. In the Malvi × Bani cross the differences in variance were quite insignificant, in spite of the large difference (over 2 mm.) between the parents.

In ginning percentage the F_2 variance was significantly greater than the F_1 in the Malvi × Bani cross only. In the other two crosses the F_2 variance was only slightly greater than that of the F_1. In Malvi × C 520 only was the F_2 variance significantly greater than the ‘ within parents ’ variance.

In *kapas* yield, there was little difference between the F_1 and F_2 variances in the Malvi × Bani cross, of which the parents gave closely similar yields. In the C 520 crosses the F_2 variance was larger than the F_1 variance, but significantly only in the Bani × C 520 cross. Actually the greatest difference in variance in the whole table was between parents and F_1 in the Malvi × Bani cross, and for this no genetic explanation can be offered.

In node number, the variance of the F_2 was significantly greater than that of the F_1 in all three crosses, but in all crosses the variance within parents was greater than that of the F_1's significantly in the Malvi crosses, and in those the variance within parents slightly exceeded that of the F_2's also.

It would be expected that the within parents and F_1 variances would be low and about equal, and would be exceeded by the F_2 variances roughly in proportion to the magnitude of the difference between the parental means. Actually, the within parents variance frequently equalled or slightly exceeded the F_2 variance, and in one case the F_1 variance also exceeded the F_2 variance, even though there was a significant difference between the parental means. Some of the discrepancy may be accounted for by the inclusion of progeny of more than one plant in the parental plots, and more than one pair of plants in the F_1 plots, but the differences between parents were in nearly all cases very much larger than any differences that might exist between plants of the same strain. Although the variance of the F_2 was usually greater than the F_1, the difference was generally comparatively small, and it must be concluded that in spite of the elimination of an environmental contribution by the block adjustment, the genetic variance was still only a small proportion of the whole. The only alternative is that the genetic variance within the parents was very large compared with that between parents, a supposition which is entirely contrary to all plant breeding experience.

With environmental differences forming so large a proportion of the total within-plot variance, single plant selection in progeny rows must be extremely inefficient, and the present data afford strong support for Harland's [1934] view that the basis of selection must be the mean of the progeny and not the single plant. Selection based on progeny means has, in fact, been a major factor in the success of the selection work on Sea Island cotton carried out in the last twenty years under Harland's guidance.

Study of within-plot variances appears to be of limited value also for the investigation of genetic variance, and it will be necessary to transfer attention to covariances between generations.

V. DISCUSSION

The experiment here reported was designed for the preliminary exploration of the problem of studying genetic variance in characters of commercial value. The problem is of first importance, for on its solution depend both the elucidation of the genetics of quantitative characters and the improvement of the efficiency of plant breeding methods.

The experiment was laid out on the replicated progeny row design described in an earlier paper in this series [Hutchinson and Panse, 1937], and this contributed very largely to its success. The genetic effects brought out by the analyses of variance of plot values were very large. Large heterosis effects (due to either dominance or epistasy) were demonstrated in all crosses and all characters, even when the mean values of the parents were closely similar, giving evidence of considerable genotypic differences between the three parental strains in all characters. Between sister F_2's, also, significant differences in mean values were demonstrated in many cases, showing that the parents were far from homozygous in spite of several generations of self-fertilisation. The distribution of heterozygosity between characters was in agreement with Fisher's demonstration that selection is more powerful than random gene elimination in reducing genetic variance.

The large heterosis (using the term to cover both dominance and epistasy) effects demonstrated in the analyses of plot values require careful investigation. It is extremely important for the theory of quantitative inheritance to study the extent of the incidence of dominance and epistasy but there appear to be very few records of experiments in which the two can be distinguished. Rasmusson [1935] concluded from his work on *Pisum* that factor interactions of the type here discussed under the term epistasy are of widespread occurrence. The present data do not distinguish between epistasy and dominance, but the two phenomena appear to be closely related, in that the same selective forces may be expected to give rise to both. Demonstration of widespread occurrence of epistasy would render necessary a more elaborate theory of the action of genes affecting quantitative characters than the simple cumulative hypothesis now favoured.

It is important to note the connection between heterosis and selection. It has been shown above that heterosis is always in the direction to be expected if it has resulted from the action of selection. Data on the inheritance of petal length [Hutchinson, 1931] and leaf shape [Hutchinson, 1934] in Asiatic cottons were examined for evidence in support of this view. Yellow long, and short white petal, and narrow and broad leaf occur in varying proportions in the crop populations of *G. arboreum* var. *neglectum* in India, and it has been shown [Hutchinson and Ghose, 1937,1] that the balance of selective forces favours a mixture of genotypes with regard to these factors, and the composition of the mixture varies from place to place in response to changes in selective forces. Since there is no steady selection in one direction either on leaf shape or on petal length, there should be no evidence of heterosis. This is borne out by the genetic data. In the main factor pairs, the heterozygote is close to the mean of the homozygotes both in petal length and leaf shape, and apart from asymmetry in the leaf shape distribution resulting from the segregation of the main factor pair, there is no evidence of heterosis bias in

F_2's either between closely related types, where few genes besides the main factor pair segregated, or between members of different species, where segregation occurred for a large group of minor factors.

It may be noted that on the selection theory of the origin of heterosis, Rasmusson's [1935] *Pisum* types show evidence of selection for late flowering.

The differences observed between F_2's from sister F_1 plants illustrate an important obstacle to the study of genetic variance. Even in strains self-fertilised and line-bred for some generations, genetic variance is likely to persist in some characters, especially those not subject to direct selection during the line-breeding process. Such genetic variance will make an unknown contribution to the variance of the F_1 and later generations. The only way to avoid it with certainty appears to be to study F_2 and later generations from a single F_1 plant, and make no attempt to derive information on variance from comparisons involving the F_1. Where back-crosses are required it will not be possible to eliminate the uncertainty arising from the inclusion of genetic variance from the back-cross parent, but where it is possible to maintain the actual plants used as parents of a cross, back-crosses should be made between a single F_1 plant (also used for the production of selfed seed for the F_2) and the actual plants used as parents of the cross.

An attempt to estimate genetic variance from a study of within-plot variances was disappointing. It appears that by far the greater part of the within-plot variances, even after adjustment for block differences and allowance for the effect of inclusion of sibs in the parentage of the F_1, was environmental in origin, and genetic effects seemed to be of much less importance than was indicated by the analyses of plot values. Studies of within-plot variances should be supplemented by covariance studies so as to estimate directly the relative importance of the environmental and genetic contributions. If the environmental contribution is really as large a proportion of the whole as it appears, single plant selection in progeny row breeding must be very inefficient. Covariance studies will indicate whether Harland's [1934] method of selection on progeny means can be improved upon.

The F_2 within-plot variances (Tables VII-X) throw interesting light on the relationship of the three parental types. As is pointed out above, all three strains belong to *G. arboreum* var. *neglectum*, but C 520 belongs to its forma *bengalensis* and Bani to forma *indica*. The classification of Malvi is rather uncertain, as it is intermediate between formas *bengalensis* and *indica* both morphologically and geographically. Below are given differences between parents, F_2 within-plot variances, and differences between F_2 and F_1 within-plot variances.

Cross	Difference between parents	F_2 within-plot variance	F_2-F_1 within-plot variance
Staple length—			
M × B	2·25	1·53	+0·28
M × C	0·42	2·67	+1·06
B × C	2·67	2·58	+0·78
Ginning percentage—			
M × B	5·13	6·99	+3·04
M × C	3·77	9·89	+0·78
B × C	8·90	9·35	+1·38
Kapas yield—			
M × B	33·3	96·33	—3·24
M × C	93·4	75·22	+10·25
B × C	62·7	69·99	+26·05
Node number—			
M × B	1·21	1·52	+0·53
M × C	0·74	2·54	+1·03
B × C	0·47	2·16	+0·86

Except in ginning percentage for which the Malvi strain used is not typical of Malvi as a whole, the excess of the F_2 variance over the F_1 is least in the Malvi × Bani cross, irrespective of the magnitude of the differences between the parents. This suggests that these two strains are more closely related to each other than they are to C 520, and that Malvi properly belongs to forma *indica*.

VI. SUMMARY

Three strains of *G. arboreum* var. *neglectum* were crossed in all three possible ways, and parents, F_1's and F_2's grown in the same year in a ten-block randomised progeny row experiment.

Analyses of variance were carried out on plot values for germination, node number, *kapas* yield, staple length and ginning percentage. Strong heterosis was demonstrated in all characters, the F_1 differing from the mean of the parents, and the F_2 usually falling between the F_1 and the mean of the parents. The direction of the heterosis bias was in all cases that which would be expected if heterosis was due to effects of selection. In node number the bias was towards a low number, and in other characters towards high values.

The importance of dominance and epistasy as causes of heterosis is discussed. The present data do not distinguish between the two, but it is pointed out that both may be expected to result from the action of selection.

Differences between F_2 progenies from sister F_1 plants demonstrated the existence of genetic variance within the parental strains. Its distribution was as would be expected if selection is more efficient than random elimination of genes in reducing genetic variance.

Within-plot variances were calculated for node number, *kapas* yield, staple length and ginning percentage. An adjustment was made for block differences and in staple length this resulted in a reduction in variance of from 15 to 31 per cent. Even after the adjustment it is concluded from the ratio of F_2 to F_1 variances that the environmental contribution remained a very high proportion of the total variance. Single plant selection in progeny rows is therefore likely to be inefficient, and estimates of within-plot variance of low value for genetic studies.

From the within-plot variances in F_2 it is concluded that Malvi is more closely related to Bani (forma *indica*) than to C 520 (forma *bengalensis*).

VII. ACKNOWLEDGMENTS

Though the preliminary experiments of Mr. Kubersingh have not been referred to in this paper, the design of the one here reported owes much to the experience he freely placed at our disposal. We are glad to acknowledge our indebtedness to him for advice and assistance.

The senior author discussed the data here reported with Prof. R. A. Fisher. His comments and suggestions have been invaluable to us in their analysis and presentation.

Our thanks are also due to Mr. S. A. Khargonekar for assistance in some of the statistical calculations.

REFERENCES

Fisher, R. A. (1918). *Trans. Roy. Soc. Edin.* **52**, 399

——— (1922). *Proc. Roy. Soc. Edin.* **42**, 321

——— (1931). *Biol. Rev.* **6**, 345

Fisher, R. A.; Immer, F. R. and Tedin, O. (1932). *Genetics* **17**, 107

Harland, S. C. (1934). *Second Conf. on Cotton Gr. Prob. (E. C. G. C., London)*

Hutchinson, J. B. (1931). *J. Gen.* **24**, 325

——— (1934). *J. Gen.* **28**, 437

——— (1936). *J. Gen.* **32**, 399

——— (1937). *Conf. Sci. Workers on Cotton in India (I. C. C. C., Bombay)*

Hutchinson, J. B. and Panse, V. G. (1937). *Ind. J. Agric. Sci.* **7**, 531

Hutchinson, J. B. and Ghose, R. L. M. (1937,1). *Ind. J. Agric. Sci.* **7**, 1

——— (1937,2). *Ind. J. Agric. Sci.* **7**, 233

Rasmusson, J. (1933). *Hereditas* **17**, 45

——— (1935). *Hereditas* **20**, 161

TABLE I

Summary of analyses of variance of staple length

Due to	Degrees of freedom	Malvi × Bani		Malvi × C 520		Bani × C 520	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	8	3·088	V. small	4·073	V. small	3·118	V. small
Between parents	1	22·670	V. small	0·803	Large	32·000	V. small
Between generations	2	1·365	0·05	1·693	0·01	7·682	V. small
Between F_2 progenies	3	0·691	0·05	0·044	Large	0·764	0·05
Error	48	0·169	..	0·381	..	0·201	..

Significance of differences in staple length

	Malvi × Bani	Malvi × C 520	Bani × C 520
Between parents	Bani 25·54 Malvi 23·29	Malvi 23·29 C 520 22·87	Bani 25·54 C 520 22·87
Between generations	F_2 24·88 F_1 24·86 M. of parents 24·41	F_1 23·77 F_2 23·13 M. of parents 23·08	F_2 25·33 F_1 25·09 M. of parents 24·20
Between F_2 progenies	881 25·20 879 25·02 880 24·71 882 24·59	878 23·22 875 23·15 877 23·08 876 23·07	871 25·72 872 25·33 874 25·24 873 25·02

TABLE II

Summary of analyses of variance of ginning percentage

Due to	Degrees of freedom	Malvi × Bani		Malvi × C 520		Bani × C 520	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	8	6·08	V. small	4·29	V. small	5·74	V. small
Between parents	1	118·07	V. small	64·22	V. small	356·45	V. small
Between generations	2	2·74	0·05	9·48	0·01	19·71	V. small
Between F_2 progenies	3	0·38	Large	1·20	Large	2·72	>0·05
Error	48	0·736	..	1·077	..	1·120	..

Significance of differences in ginning percentage

Due to	Malvi × Bani	Malvi × C 520	Bani × C 520
Between parents	Malvi 36·07 Bani 30·94	C 520 39·84 Malvi 36·07	C 520 39·84 Bani 30·94
Between generations	F_1 34·46 F_2 33·89 M. of parents 33·50	F_1 39·64 F_2 38·86 M. of parents 37·95	F_1 37·93 F_2 36·46 M. of parents 35·39
Between F_2 progenies	881 34·10 879 34·00 880 33·82 882 33·63	878 39·30 877 38·99 876 38·72 875 38·44	872 37·06 874 36·77 871 36·18 873 35·84

TABLE III

Summary of analyses of variance of kapas *yield*

Due to	Degrees of freedom	Malvi × Bani		Malvi × C 520		Bani × C 520	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	8	3473·5	0·01	2141·4	0·01	1042·9	Large
Between parents	1	4823·8	0·05	37256·3	V. small	13975·7	0·01
Between generations	2	10962·1	0·01	24922·7	V. small	12087·2	0·01
Between F_2 progenies	3	2093·3	Large	2469·3	0·05	354·3	Large
Error	*47	1162·1	..	717·8	..	1326·0	..

Significance of differences in kapas *yield*

Due to	Malvi × Bani				Malvi × C 520				Bani × C 520			
Between parents	Malvi	Bani			Malvi	C 520			Bani	C 520		
	238·7	205·4			221·5	128·1			195·0	132·3		
Between generations	F_1	F_2	M. of parents		F_1	F_2	M. of parents		F_1	F_2	M. of parents	
	278·1	253·2	221·2		267·5	178·6	175·5		217·3	203·3	163·6	
Between F_2 progenies	882	880	879	881	878	876	875	877	872	871	874	873
	268·9	262·3	248·4	235·0	196·8	194·9	171·0	163·0	210·0	206·1	200·8	194·5

* One less for regression. 45 in the Malvi × Bani cross, 2 missing plots have been estimated. Adjusted values for parents differ in different crosses owing to differences in the regression of stand.

TABLE IV

Summary of analyses of variance of node number

Due to	Degrees of freedom	Malvi × Bani		Malvi × C 520		Bani × C 520	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	8	0·18	Large	0·53	0·05	0·57	V. small
Between parents	1	6·60	V. small	2·49	0·01	0·98	V. small
Between generations	2	1·05	0·01	0·95	0·05	0·66	0·01
Between F_2 progenies	3	1·04	0·01	0·63	0·05	1·53	V. small
Error	48	0·17	..	0·24	..	0·12	..

Significance of differences in node number

Due to	Malvi × Bani				Malvi × C 520				Bani × C 520			
Between parents	Malvi	Bani			Malvi	C 520			C 520	Bani		
	11·51	10·30			11·51	10·77			10·77	10·30		
Between generations	M. of parents	F_2	F_1		M. of parents	F_2	F_1		F_2	M. of parents	F_1	
	10·91	10·51	10·47		11·14	11·06	10·60		10·74	10·53	10·34	
Between F_2 progenies	880	882	879	881	875	876	877	878	871	872	873	874
	10·93	10·62	10·32	10·17	11·27	11·23	11·06	10·69	11·24	10·87	10·56	10·29

TABLE V

Summary of analyses of variance of germination

Due to	Degrees of freedom	Malvi × Bani		Malvi × C 520		Bani × C 520	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	9	7·21	Large	6·80	Large	4·44	Large
Between parents	1	39·20	0·01	2·45	Large	61·25	0·01
Between generations	2	8·19	Large	39·93	0·01	2·90	Large
Between F_2 progenies	3	13·53	0·05	26·29	0·01	9·97	Large
Error	54	5·35	..	5·08	..	8·56	..

Significance of differences in germination

Due to	Malvi × Bani	Malvi × C 520	Bani × C 520
Between parents	Bani 14·2 Malvi 11·4	Malvi 11·4 C 520 10·7	Bani 14·2 C 520 10·7
Between generations	F_1 13·7 M. of parents 12·8 F_2 12·3	F_1 14·5 F_2 12·4 M. of parents 11·0	F_1 13·1 M. of parents 12·4 F_2 12·2
Between F_2 progenies	881 880 882 879 13·7 12·8 11·5 11·2	878 877 875 876 14·1 13·4 11·2 10·8	872 874 873 871 13·3 12·9 11·5 11·3

TABLE VI

Within-plot variances in staple length (Block classification ignored)

Cross	Generation	Degrees of freedom	Mean square	$\frac{1}{2}\log_e$	*P*	
Malvi	Parent	95	2·164	0·386	0·2	
Bani	Parent	122	1·692	0·263		0·05
C 520	Parent	75	1·474	0·194	Large	
Malvi × Bani	Parents	217	1·899	0·321	Large	
	F_1	111	1·744	0·278		Large
	F_2	419	1·802	0·256	Large	
Malvi × C 520	Parents	170	1·860	0·310	Large	
	F_1	121	1·939	0·331		0·05
	F_2	406	3·279	0·594	0·05	
Bani × C 520	Parents	197	1·609	0·238	0·05	
	F_1	110	2·136	0·380		0·05
	F_2	398	3·084	0·563	0·05	

TABLE VII

Within-plot variances in staple length (Adjusted for block differences)

Cross	Generation	Degrees of freedom	Mean square	$\frac{1}{2}\log_e$	*P*	Percentage variation eliminated
Malvi	Parent	95	1·483	0·197		31
Bani	Parent	122	1·392	0·165	All large	17
C 520	Parent	75	1·275	0·121		14
Malvi × Bani	Parents	217	1·432	0·180		25
	F_1	111	1·254	0·113	All large	28
	F_2	419	1·530	0·213		15
Malvi × C 520	Parents	170	1·391	0·165	Large	25
	F_1	121	1·611	0·238	0·05	16
	F_2	406	2·668	0·491	0·05	19
Bani × C 520	Parents	197	1·348	0·149	0·05	16
	F_1	110	1·804	0·295	0·05	15
	F_2	398	2·579	0·474	0·05	16

TABLE VIII

Within-plot variances in ginning percentage (Adjusted for block differences)

Cross	Generation	Degrees of freedom	Mean square	½ log$_e$	P	
Malvi	Parent	93	4·520	0·754	0·01	
Bani	Parent	121	8·371	1·062		0·01
C 520	Parent	73	11·251	1·210	>0·05	
Malvi × Bani	Parents	214	6·698	0·951	0·01	
	F_1	111	3·953	0·687		Large
	F_2	412	6·995	0·973	0·01	
Malvi × C 520	Parents	166	7·480	1·006	Large	
	F_1	119	9·108	1·104		0·05
	F_2	393	9·886	1·146	Large	
Bani × C 520	Parents	194	9·455	1·123		
	F_1	106	7·968	1·038	All large	
	F_2	387	9·350	1·118		

TABLE IX

Within-plot variances in kapas *yield (Adjusted for block differences)*

Cross	Generation	Degrees of freedom	Mean square	½ log	P	
Malvi	Parent	94	75·314	2·161	Large	
Bani	Parent	121	65·922	2·094		0·05
C 520	Parent	75	46·651	1·921	0·05	
Malvi × Bani	Parents	215	70·028	2·125	0·01	
	F_1	111	99·574	2·300		0·01
	F_2	417	96·330	2·284	Large	
Malvi × C 520	Parents	169	62·594	2·068	Large	
	F_1	122	64·972	2·087		Almost 0·05
	F_2	401	75·217	2·160	Large	
Bani × C 520	Parents	196	58·548	2·035	Large	
	F_1	97	43·939	1·892		Almost 0·05
	F_2	398	69·991	2·124	0·01	

TABLE X

Within-plot variances in node number (Adjusted for block differences)

Cross	Generation	Degrees of freedom	Mean square	$\frac{1}{2} \log_e$	P
Malvi	Parent	88	2·991	0·548	0·01
Bani	Parent	112	0·951	—0·025	0·05
C 520	Parent	69	2·036	0·356	0·01
Malvi × Bani	Parents	200	1·849	0·307	0·05
	F_1	101	0·993	—0·004	Large
	F_2	380	1·521	0·210	0·05
Malvi × C 520	Parents	157	2·571	0·472	0·05
	F_1	115	1·509	0·206	Large
	F_2	362	2·542	0·466	0·05
Bani × C 520	Parents	181	1·365	0·156	Large
	F_1	96	1·298	0·130	0·05
	F_2	372	2·155	0·384	0·05

SHORTENING THE REST PERIOD OF THE POTATO (*SOLANUM TUBEROSUM* L.)

BY

B. P. PAL

AND

PUSHKAR NATH*

Imperial Agricultural Research Institute, New Delhi

(Received for publication on 29th June 1938)

(With Plate LIX and four text-figures)

CONTENTS

	PAGE
INTRODUCTION	777
PREVIOUS STUDIES	778
EXPERIMENTAL METHODS	778
EXPERIMENTAL RESULTS	780
DISCUSSION	784
SUMMARY	785
REFERENCES	786

Introduction

IN several parts of India two or even three crops of potatoes are raised in a year. This means that immediately or soon after a particular crop is harvested, another crop has to be planted. In such cases, the tubers from the former cannot be used for planting the succeeding crop, owing to the fact that potato tubers have a period of rest of two to three months, or even more, after harvesting. The experiments described in the present paper are the outcome of an attempt to investigate whether the methods used in America by Denny and others to abridge the rest period of the potato could be successfully employed under Indian conditions. It was also thought that, whether or not the experiments led to results which would be capable of large-scale utilization by potato growers, any information which they yielded on the shortening of the rest period by artificial methods of the varieties of potato commonly grown in India would be of value to potato breeders in this country.

It should perhaps be mentioned that among the numerous wild and cultivated species recently discovered in Central and South America there are a few which are reported to have a very short or no rest period, *e.g.*, *S. boyacense* Juz. et Buk., *S. Kesselbrenneri*, *S. phureja* Juz. et Buk. and *S. Rybinii*

---

[*] At present Superintendent of the Potato Breeding Sub-station, Simla.

Juz. et Buk. [Bukasov, 1933]. This has opened up the possibility of developing commercially desirable varieties with a short resting period by hybridising these species with the common cultivated potato (*S. tuberosum* L.).

Previous studies

A survey of the literature indicates that both physical and chemical methods of shortening the rest period have been applied by previous investigators. Appleman [1916] pointed out that potatoes may be sprouted at any time simply by removing the skins and supplying favourable growing conditions. The effect of a large number of chemicals and gases on the rest period of the potato has been intensively studied, especially by Denny and his colleagues [Denny, 1926, 1 ; 1926, 2 ; 1928 ; 1933 ; Denny and Miller, 1935 ; Miller and Denny, 1936 ; McCallum, 1909, van der Goot, 1926 ; Cooper, 1928 ; Rosa, 1928, 2 ; Werner, 1931 ; Thornton, 1933 ; Stuart and Milstead, 1934 ; Kawakami, 1937, 1 ; 1937, 2 ; etc.]. Denny [1926, 1] tested more than 200 different chemicals and has also investigated (*vide* later publications) the factors determining the effectiveness and practicability of their use for breaking the rest period. Ethylene chlorhydrin and the thiocyanates of sodium or potassium have been found to be among the most effective. The conditions necessary for a maximum effect appear to vary with the tuber maturity at the time of harvesting and also with the variety, locality, season, humidity, temperature, etc. Temperature is particularly important [Denny, 1928] and the chemical treatments are effective only within certain ranges of temperature. Suitable doses of the chemicals have also to be worked out : if the concentration of the chemical used is too high, injury or even death of the seed-pieces may result.

Loomis [1927], Rosa [1928, 1], Cooper [1928] and Wright and Peacock [1934] showed that storing resting tubers at relatively high temperatures (about 30° to 35°C.) was also effective in shortening the rest period. But the time required is about thirty days, and, even after a period of high temperature storage, treatment with chemicals is effective in hastening sprouting [Denny and Miller, 1935]. Smith [1929] stated that moist storage at 25°C. is one of the most effective methods of breaking the rest period.

Although the treatment of resting tubers to hasten sprouting has been so extensively investigated, none of the methods of treatment has yet been adopted by commercial growers. Denny and Miller [1935], however, have referred to the possibility of treating freshly-harvested tubers in the north of the United States in 'car-lot' quantities and shipping the treated tubers to the localities in the Southern States in which they are to be planted.

Experimental methods

EXPERIMENTS OF 1934-35

Experiment 1

Tubers of the variety Khabrar grown near Ramgarh in the Kumaon Hills and dug on September 27 were obtained from Mr. P. R. Sherred of the

Allen Orchard Estates, and treatments were commenced at Pusa* on October 5, *i.e.*, eight days after harvest. The tubers were mature but dormant. For the purpose of the experiment tubers of approximately uniform size and weight were selected. Except where otherwise stated, whole (*i.e.*, uncut) tubers were used for planting.

The treatments given were as follows :—

A. Control.—No treatment.

B. Ethylene chlorhydrin vapour method.—Whole tubers were placed under bell-jars of 6·5 litres capacity and 6·5 c.c. of ethylene chlorhydrin (40 per cent aqueous solution) in shallow glass dishes were placed in each jar. The jar was then sealed with vaseline to a glass plate. After twenty-four hours the tubers were transferred to glass containers and kept under ordinary laboratory conditions ; they were planted out after a week.

C. Ethylene chlorhydrin dip method for whole tubers.—Clean whole tubers were dipped in a solution of ethylene chlorhydrin (30 c.c. of 40 per cent ethylene chlorhydrin per litre of water), one by one, and removed at once from the dipping solution. They were then kept for twenty-four hours in a closed jar which had a volume of about twice the volume of the sample after which they were stored for a week under ordinary conditions, before planting.

D. Ethylene chlorhydrin dip method for cut tubers.—Each tuber was cut, first longitudinally, and then, transversely ; of the four pieces resulting therefrom, three were discarded, only one of the pieces from the crown end possessing a few apical buds being used for the experiment. Dipping solution and method of treating were as for treatment C above.

E. Peeling method.—Whole tubers were peeled, care being taken not to damage the eyes (a small area of skin was allowed to remain around each eye), and placed in moist saw-dust for a week. After this period they were planted out.

In Experiment 1 all the plantings were done in boxes filled with sterilised soil, at the rate of twelve tubers per box. There were five replications making a total of sixty tubers for each treatment.

Experiment 2

The material was the same as that used in Experiment 1 but the treatments were commenced on October 16, *i.e.*, nineteen days after lifting. Planting was done on October 24 in the field in randomised blocks with six replications. The total number of tubers per treatment was forty-five.

The five treatments described in Experiment 1 were repeated. In addition to these, three other treatments were tried, *viz.*, (1) Keeping unpeeled whole tubers in moist saw-dust for a week, after which they were planted out, (2) Soaking unpeeled tubers in water for a day and keeping them in moist saw-dust for six days after which they were planted out, and (3) Keeping tubers in an incubator at a constant temperature of 35°C. for two weeks after which they were planted out. None of the three latter treatments, however, was successful, and the results are therefore not further referred to.

---

* All the experiments described in the present paper were conducted in the Botanical Section of the Imperial Agricultural Research Institute at Pusa, before the transfer of the Institute to New Delhi.

EXPERIMENTS OF 1935-36

Experiment 3

The variety Khabrar was again used and tubers lifted on October 21 at Ramgarh were railed to Pusa and treatments commenced on October 31. Plantings were done a week later, on November 7, in the field. A randomised blocks layout was adopted, with six replications. The total number of tubers per treatment was sixty.

The five treatments described in Experiment 1 were repeated.

Experiment 4

The local white variety, called Pusa White in this paper for convenience, was used. As this variety is normally harvested in March in Pusa, dormant tubers for the experiment were obtained from the summer sowing at Simla. The details of treatment, planting and layout were exactly as for Experiment 3 (above).

Experimental results

IMMEDIATE EFFECTS OF THE TREATMENTS

In the interval between the commencement of the treatments and the planting of the tubers in the soil, the effects of the treatments became visible in certain of the latter (Plate LIX, fig. 1). These are briefly described below.

Treatment A

There was no apparent change.

Treatment B

Minute scaly sprouts appeared from almost every eye on each tuber.

Treatments C and D

Sprouts similar to those in B appeared but their development was not so good.

Treatment E

This treatment gave the most striking results, and a strong sprout (occasionally 2 or 3 sprouts) developed from the crown end of each tuber. There was, however, a larger loss, due to rotting of tubers, than in other treatments. It was found, however, that the loss due to this cause could be greatly reduced by adding a smaller quantity of water to the saw-dust at the time of moistning it. Further it was observed that, within the same lot, the number of tubers which rotted in the upper layers was appreciably less than in the lower layers.

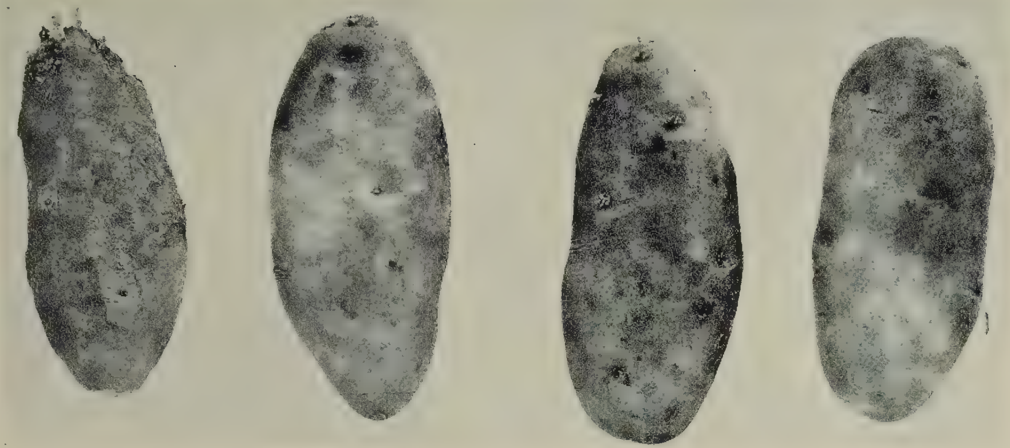


FIG. 1. Typical treated tubers from the following treatments (photographed before planting in the soil) :—
(*Left to right*) : Peeling, Ethylene chlorhydrin dip method, Ethylene chlorhydrin vapour method, Control

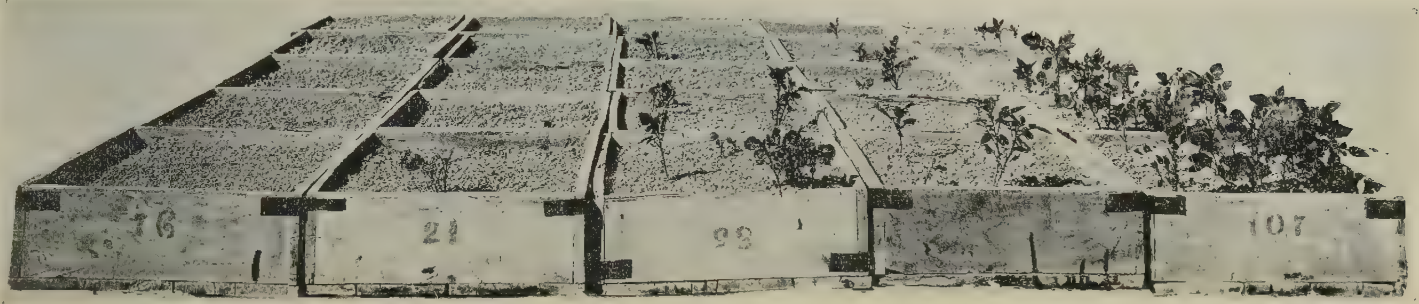


FIG. 2. Relative growth under the several treatments a month after planting in the soil :—
(*Left to right*) : Control, Ethylene chlorhydrin dip method for whole tubers, Ethylene chlorhydrin dip method for cut tubers, Ethylene chlorhydrin vapour method, Peeling

OTHER EFFECTS OF THE TREATMENTS

The main object of the experiments reported in this paper was to investigate the effectiveness of the various treatments mentioned in the preceding section, in abridging the rest period of potato tubers. Weekly counts of germination* were taken and the results are presented graphically in Figs. 1-4. The comparative plant growth attained under the various treatments in Experiment 1 is illustrated in Plate LIX, fig. 2. Brief comments on the results are made below :—

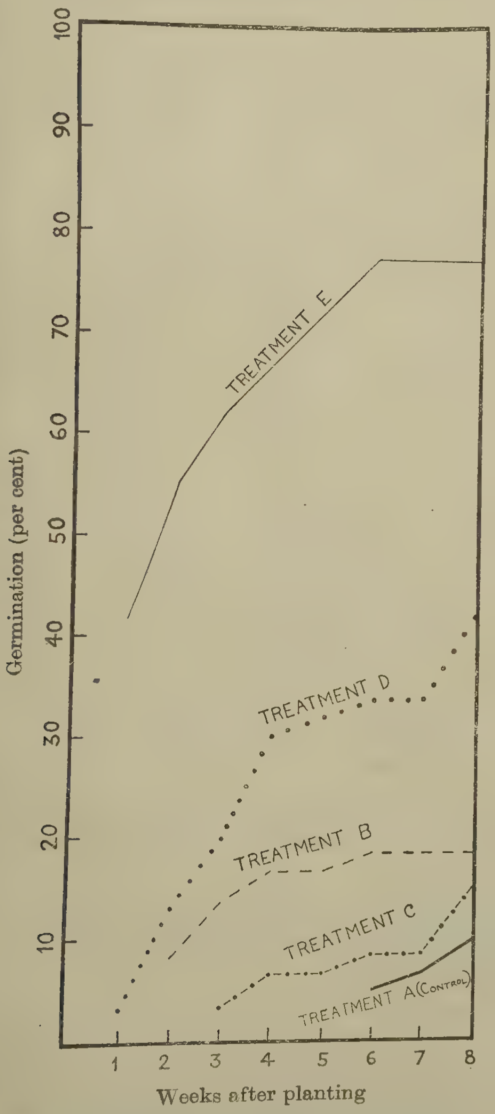


FIG. 1. Differences in rates of germination of treated and untreated resting tubers (Experiment 1)

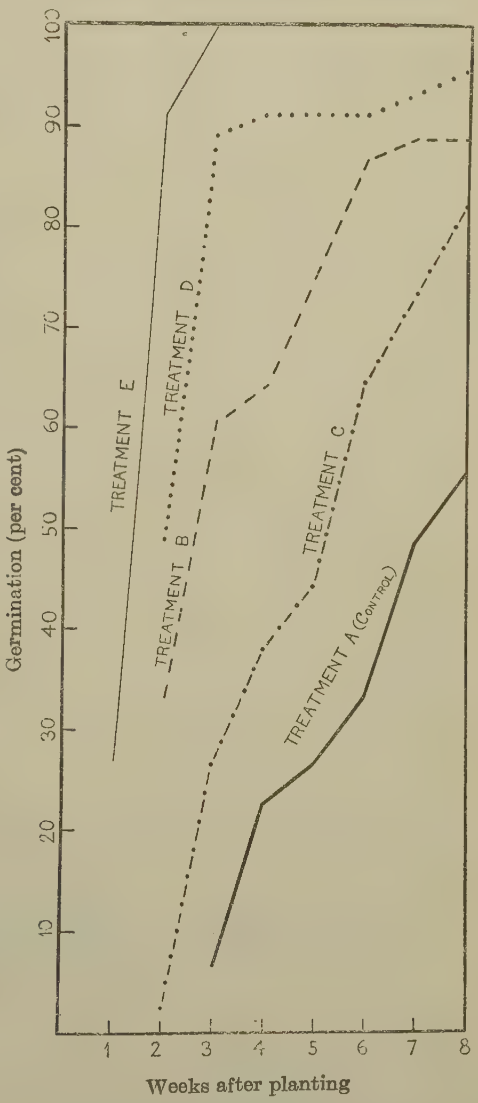


FIG. 2. Differences in rates of germination of treated and untreated resting tubers (Experiment 2)

---

* The appearance of the shoot above the ground, after planting, is for convenience termed 'germination' in this paper.

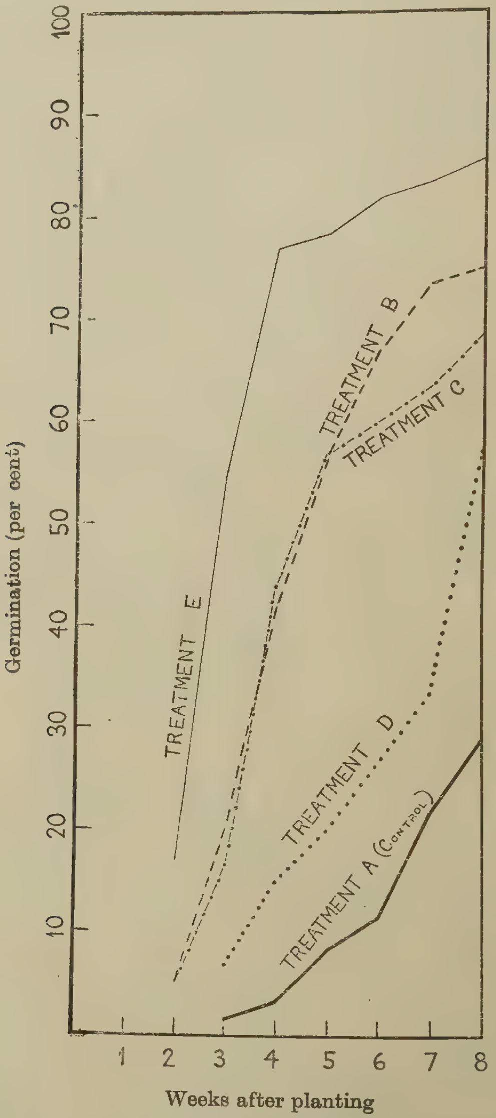


Fig. 3. Differences in rates of germination of treated and untreated resting tubers (Experiment 3)

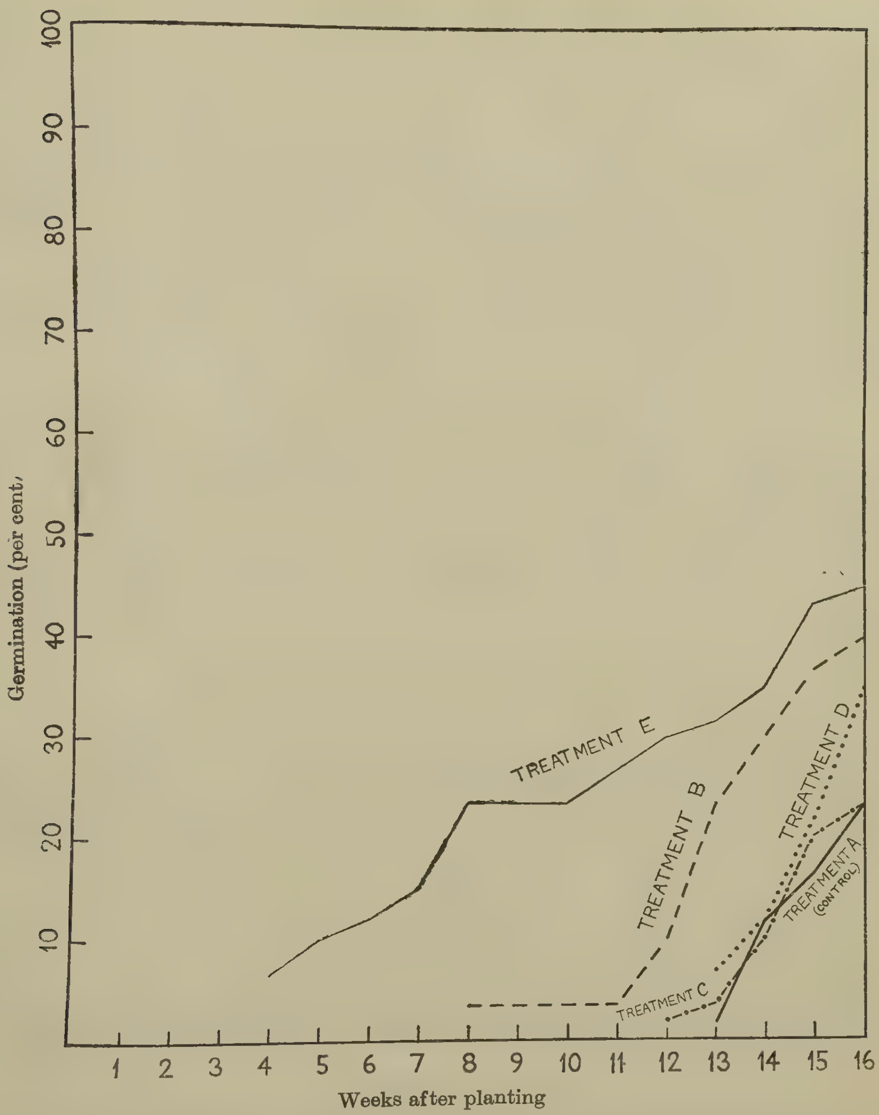


FIG. 4. Differences in rates of germination of treated and untreated resting tubers (Experiment 4)

Effect of peeling (Treatment E)

The tubers which were given this treatment usually germinated earlier than those subjected to the other treatments. Further, the rate of germination during the first few weeks was much higher than for the next best treatments, and the period required for completion of germination was decidedly smaller. For instance, in Experiment 1, the total germination of tubers under this treatment was completed within six weeks, and in Experiment 2, within three weeks.

Effect of ethylene chlorhydrin dip method for cut tubers (*Treatment D*)

Next to peeling, this treatment gave the best results in Experiments 1 and 2. In Experiments 3 and 4, however, it was surpassed by treatment B, and in the case of Experiment 3, by treatment C also.

Effect of ethylene chlorhydrin vapour method (*Treatment B*)

This method was, on the whole, as successful as the ethylene chlorhydrin dip method for cut tubers.

Effect of ethylene chlorhydrin dip method for whole tubers (*Treatment C*)

While effective to a certain extent, this treatment gave decidedly poorer results than the other treatments except in Experiment 3 where it gave quite good results. In Experiment 4, where the variety Pusa White was used, there was no response to this treatment.

It is noteworthy that the response of Pusa White to all the treatments (Experiment 4) was neither so quick nor so uniform as that of the Khabrar variety.

COIMBATORE EXPERIMENTS

Rao Bahadur B. Viswa Nath has very kindly allowed us to refer to ths experiments conducted by him in 1932 at Coimbatore. In these experimente both whole tubers and cut pieces of eight varieties of potatoes (Great Scot, Early Market, Alnwick Castle, Arran, Comrade, Ben Cruachan, King Edward Kerr's Pink and Golden Wonder) were treated with solutions of potassium sulphocyanide, ammonium thiocyanate, thio-urea and sodium nitrate.

Treatment with potassium sulphocyanide and thio-urea generally gave good results but ammonium thiocyanate fell short of the control in the case of most of the varieties ; sodium nitrate was uniformly unsatisfactory. An interesting observation was that the variety Golden Wonder failed to respond to any of the treatments except soaking cut pieces in thio-urea solution.

Discussion

It is evident from the results mentioned in the foregoing pages that the methods devised by Denny and others for shortening the rest period of potato tubers can be applied equally successfully in India. It is equally true that at present there is no likelihood of such methods being utilised on a commercial scale in this country. The simplest and the most uniformly successful method of breaking the rest period is peeling the tubers. There are, however, obvious difficulties in arranging for the peeling and moist storage of large quantities of tubers, and unless adequate care is taken, there are likely to be large losses from rotting of tubers under such conditions.

Among the chemicals used for the purpose, ethylene chlorhydrin is perhaps the best. Miller and Denny [1936] have shown that it can safely be used to break the rest period under a variety of conditions. In all the chemical treatments, however, the most suitable concentration of the chemical, and optimum conditions for the treatment of each variety have to be carefully worked out. It is evident that the value of any treatment for curtailing the rest period is its effectiveness in securing a satisfactory percentage of germination in a minimum period of time ; the uniformity of action of a given treatment is therefore also a factor of considerable importance. The chemical methods are obviously not methods to be used except in trained hands.

Whatever may be the prospects of the adoption of such methods by potato-growers and dealers, there can be no question of their importance for use in experimental work. By thus breaking the dormancy of the tubers, it is sometimes possible to save a season in breeding or genetical work, and we have personally had recourse to such means, in our breeding work with potatoes.

A point of interest that arises is whether the yields of plants grown from tubers subjected to treatments for shortening the rest period are inferior to the yields that would result from the use of non-treated non-resting tubers. Although but little definite evidence appears to be available on this point, there seems to be no reason why any decrease in yield should ensue. Kawakami [1937, 2] states that treated sets yielded heavily, in one case outyielding untreated by 300·8 bushels per acre, but as his paper is in Japanese it is not possible to assess the value of his data. The present series of experiments does not throw any light on the subject : naturally enough the plants from treatments which resulted in earlier germination and, therefore, a longer growing period, gave better yields than those from treatments where the germination took place later.

Summary

1. Experiments were carried out to investigate the effectiveness of several treatments in shortening the rest period of potato tubers.

2. The most successful treatment was peeling the tubers and storing them in moist saw-dust for a week. The response to this method was the quickest and also the most uniform.

3. The ethylene chlorhydrin vapour method and the ethylene chlorhydrin dip method for cut tubers were also distinctly successful although the results were not quite so good as with peeling.

4. The fourth method tested, the ethylene chlorhydrin dip method for whole tubers, proved inferior to all the treatments except the untreated control.

5. It is pointed out that though at present such methods of breaking the rest period of potato tubers are unlikely to be adopted by commercial growers, they are of value to potato breeders and geneticists.

6. Previous studies on the subject are briefly referred to.

REFERENCES

Appleman, C. O. (1916). *Bot. Gaz.* **61**, 265-94

Bukasov, S. M. (1933). *Lenin. Acad. Agric. Sci. Inst. Pl. Ind.* (Leningrad) 1933, p. 44

Cooper, J. R. (1928). *Ann. Rept. Arkansas Agric. Expt. Stn.* p. 63

Denny, F. E. (1926, 1). *Amer. J. Bot.* **13**, 118-25

————(1926, 2). *Amer. J. Bot.* **13**, 386-95

————(1928). *Amer. J. Bot.* **15**, 395-404

————(1933). *J. Assoc. Offic. Agric. Chem.* **16**, 1926

Denny, F. E. and Miller, L. P. (1935). *Contrib. Boyce Thomp. Inst.* **7**, 157-81

Kawakami, K. (1937, 1). *Proc. Crop Sci. Soc. Jap.* **9**, 235-51 (Jap. with English summary)

———— (1937, 2). *Agric. and Hort.* **12**, 713-22

Loomis, W. E. (1927). *Plant Physiol.* **2**, 287-302

McCallum, W. B. (1909). *Ann. Rept. Ariz. Agric. Expt. Stn.*, 584-86

Miller, L. P. and Denny, F. E. (1936). *Contrib. Boyce Thomp. Inst.* **8**, 121-36

Rosa, J. T. (1928, 1). *Hilgardia* **3**, 99-124

———— (1928, 2). *Hilgardia* **3**, 125-142

Smith, O. (1929). *Hilgardia* **4**, 273-306

Stuart, W. and Milstead, E. H. (1934). *U. S. Dept. Agric. Tech. Bull.* **415**, 31 pp.

Thornton, N. C. (1933). *Contrib. Boyce Thomp. Inst.* **5**, 471-81

Van der Goot, P. (1926). *Landbouw* (*Buitenzorg*) **2**, 415-25

Werner, H. O. (1931). *Nebraska Agric. Expt. Stn. Res. Bull.* **57**, 39 pp.

Wright, R. C. and Peacock, W. M. (1934). *U. S. Dept. Agric. Tech. Bull.* **424**, 21 pp.

AGRICULTURAL METEOROLOGY: FREQUENCY OF DAYS WITH HAIL-STORMS IN INDIA*

BY

L. A. RAMDAS, M.A., Ph.D.
Agricultural Meteorologist,
V. SATAKOPAN, M.A.
AND
S. GOPAL RAO, B.A.
Agricultural Meteorology Section, Meteorological Office, Poona

(Received for publication on 16th May 1938)

(With fourteen text-figures)

I. Introduction

The theory of the formation of hail-storms has been discussed by a number of workers. It is generally recognised that hail-storms and thunder-storms are similar in their origin and that hail is formed when the vertical air currents associated with a thunder cloud have sufficient velocity and extent to bring about the freezing of moisture and its precipitation as ice or hail. The experiments of Lenard and Flower show that a vertical current of air having a velocity of eight metres per second can support rain drops up to a size of 5·5 mm. in diameter. It is observed that drops of larger size are unstable. They are deformed and broken up into smaller drops when acted upon by an air current. There is, however, no such limit to the size of a hail-stone and ascending air currents which have sufficient velocity to support hail-stones several inches in diameter and weighing a pound or more do sometimes form in a hail-storm†.

Again, the section of a hail-stone reveals that the original frozen drop forming its core has received successive coatings of ice, indicating that the hail-stone has gone up and down several times in the region of the clouds, falling down as soon as the size is too much for the upward velocity of the air at the point to support it and being again carried up as soon as it reaches a region of sufficiently strong vertical velocity and so on until the stone is too heavy to be supported any longer by the ascending air currents.

---

*This investigation was undertaken in the Agricultural Meteorology Section, Poona (financed by the Imperial Council of Agricultural Research) at the instance of the International Commission on Agricultural Meteorology.

†In *Quarterly Journal of the Royal Meteorological Society*, Vol. **63**, No. 269 (1937), pp. 149-162, Bilham, E. G. and Relf, E. F. have discussed the dynamics of large hail-stones. They conclude that an upper limit of about 1·5 lb. is set to the mass attainable by a spherical hail-stone by aerodynamical considerations. More recently (*Quarterly Journal of the Royal Meteorological Society*, Vol. **64**, No. 273, 1938, pp. 3-17) Schumann finds that the values of water content of the clouds and of upward velocities are sufficient to account for hail-stones at least 8 cm. in diameter.

A study of the distribution and frequency of hail-storms is of direct interest to the farmer and it will be very useful to know which are the areas most susceptible to damage due to hail. For this purpose we have to examine all past available records and to arrange for the collection, in future, of more detailed reports concerning the intensity and duration of hail-storms and the extent of the area affected and of the damage caused by individual hail-storms*.

In the *Indian Meteorological Memoirs*, Vol. VI, Part 6, Sir John Eliot discussed the hail-storms which occurred in India during the period 1883-97. The data used in the above discussion consisted of reports of hail-storms communicated to the Meteorological Office by Collectors of districts, particularly during the period 1893-97 when special efforts were made by Sir John Eliot to collect a large amount of information. Most of these reports were fairly detailed as they were intended primarily for purposes of revenue assessment; they contain information of great value and interest regarding the intensity, extent and damaging effect on crops of the several hail-storms. The discussion of these data is the first attempt to study the occurrence of hail-storms in India.

II. DATA USED IN THE PRESENT INVESTIGATION

The reports of hail-storms sent in the daily weather telegrams by observers at the weather-reporting stations in India provide another type of information which, though very meagre in details, is nevertheless valuable for the purpose of computing the mean frequency of days with hail-storms reported from each station during a series of years. The reporting station being fixed in each case, the variability in space which affect the reports used by Sir John Eliot is avoided and maps showing the mean frequency of occurrence of hail would have a definite significance as climatological charts.

The hail reports appear in the 'remarks' column of the tables in the India Daily Weather Reports and are noted against the stations where they were recorded. As may be expected, almost invariably, hail was associated with thunder-storms. By examining the printed daily weather reports for each date, records of hail were noted down for a period of thirty-eight years from 1898 to 1935 for each of the weather-reporting stations. The data so collected were next tabulated for each station, the actual frequency of days with hail month by month for each of the years 1898-1935 being noted. Fig. 1 shows the distribution of the selected† stations (141) on a map of India. While most of these stations had recorded the occurrence of hail throughout the period 1898-1935, there were some which commenced recording later than 1898. The number of years for which each observatory had recorded hail is indicated in column 2 of Table 1.

---

*The system of collecting detailed reports from districts has been revived recently.

†At the great majority of stations the meteorological observations are made by part-time observers. It is known that the observers often fail to follow instructions regarding the reporting of weather remarks correctly. To judge the reliability or otherwise of a particular station one has to compare the data with the contemporary data of neighbouring stations and also see how far the records, in different years, of the same station are consistent.

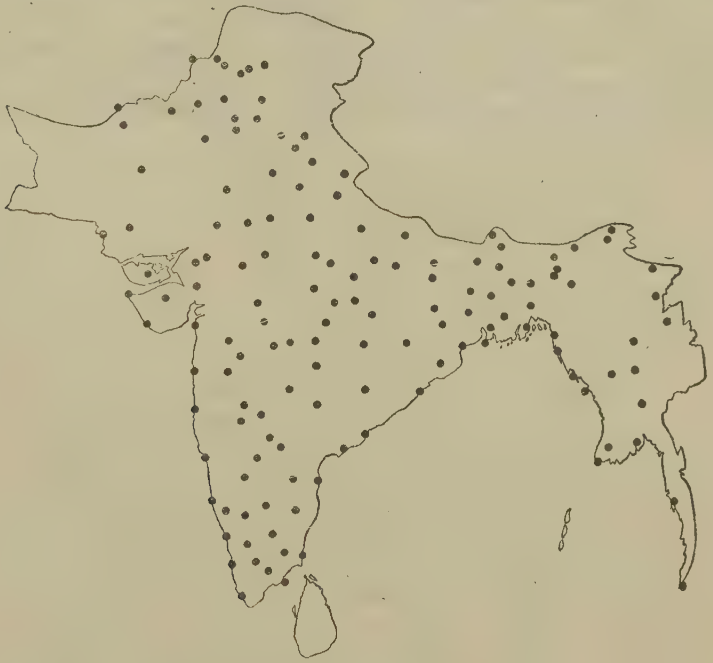


FIG. 1. Selected stations

In order to make the data of different stations strictly comparable the actual frequency figures were converted into 'frequency of days with hail-storms during 100 years'. These reduced data are given for each month and for all the months together for the 141 stations in columns 3 to 15 of Table 1.

III. SEASONAL VARIATION OF FREQUENCY OF DAYS WITH HAIL-STORMS IN DIFFERENT PARTS OF INDIA

Figs. 2 to 14 are maps showing the frequencies of days with hail-storms in 100 years, for each month of the year and for the year as a whole respectively. The maps were prepared by plotting the frequency values against each station and drawing lines of equal frequency. Details regarding the frequency intervals at which these lines have been drawn are indicated on the maps themselves. The maps show the distribution of the frequency of days with hail-storms over India as well as the variations of the frequency during the course of the year. The main features of the different monthly and annual frequency charts are summarised below :—

January (Fig. 2)

The slopes of the Himalayas and the adjoining areas in North India including Assam but excluding the plains of Sind and Bengal, are liable to hail-storms; over the central parts of the country also hail-storms occur in some years. The frequency of days with hail-storms is up to fifty in 100 years or once in two years over the Western Himalayan region, decreasing rapidly to once in twenty years elsewhere in the affected area. To the south of latitude 20° N., hail-storms are practically unknown in the month of January.

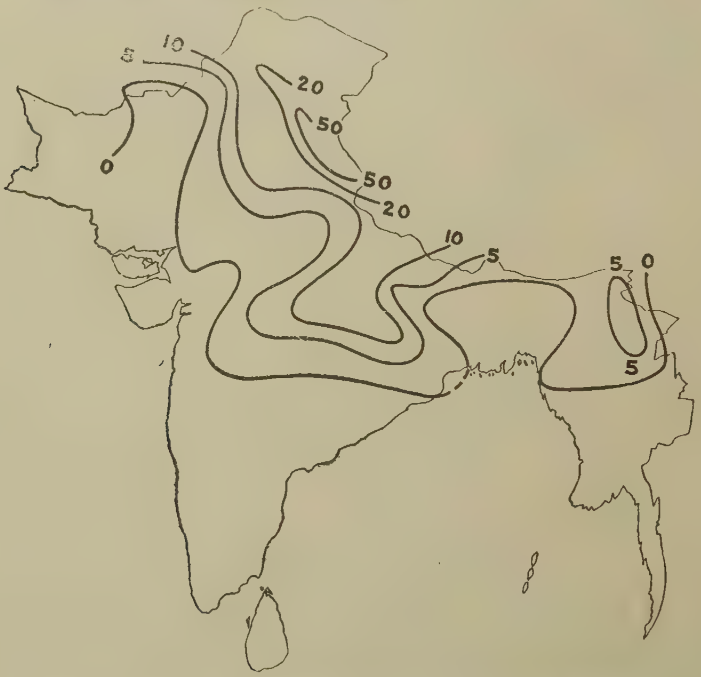


Fig. 2. Frequency of hail-storms in 100 years (January)

February (Fig. 3)

In February the frequency of days with hail-storms over the northern and central parts of India increases while some occur also in Bengal. Sind is still free from hail-storms. The frequency is up to once every year over the Western Himalayan region, once in five years over the Eastern Himalayan region and the central parts of the country and once in ten years elsewhere in the affected area. The peninsula to the south of 17 or 18° N. is free from hail-storms but Kodaikanal, a hill station, gets an occasional hail-storm.

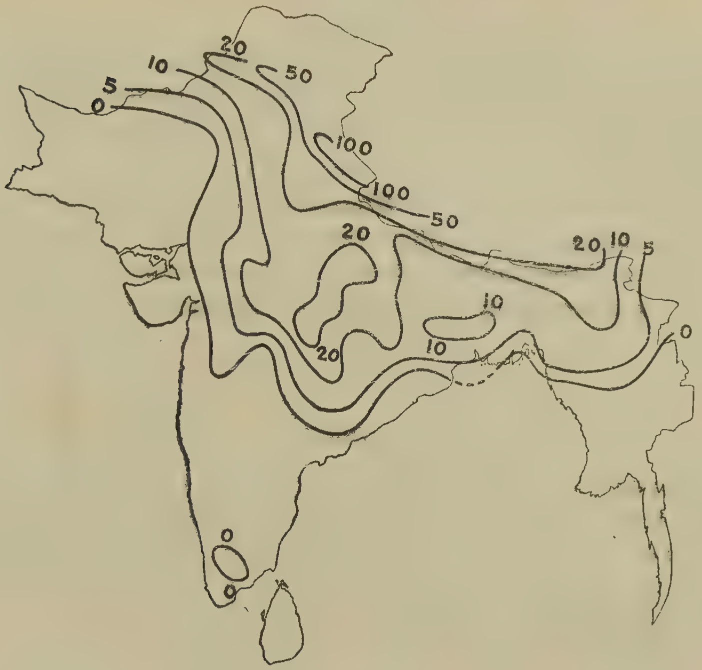

20
10
50
5
0
100
100
50
20
20
10
5
10
10
0
20
0
0

Fig. 3. Frequency of hail-storms in 100 years (February)

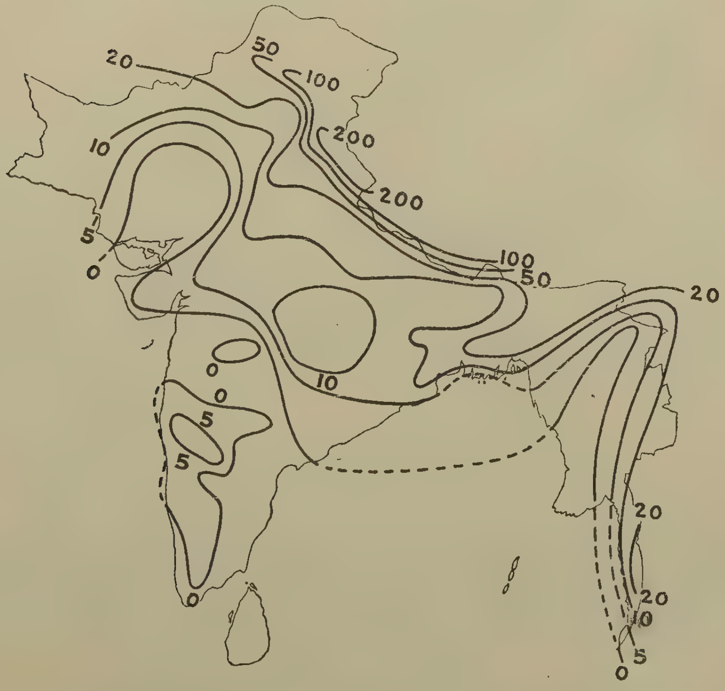

20
50
100
200
10
200
5
0
100
50
20
0
0
5
5
10
20
20
10
5
0
0

Fig. 4. Frequency of hail-storms in 100 years (March)

March (Fig. 4)

With the advent of March the area susceptible to hail-storms extends southwards so that, with the exception of Sind, North Bombay-Deccan and Madras South-East, practically the whole country has an occasional hail-storm. The frequency is up to twice a year over the Western Himalayan region, once a year over the Eastern Himalayan region, and once in five years over the central parts of the country, Bengal (where the nor'wester thunderstorms set in), and Tenasserim. Elsewhere the frequency is below once in twenty years, except at Kodaikanal where a hail-storm occurs once in three years.

April (Fig. 5)

April is similar to March, except that the frequency of days with hail is now up to once a year over the North-West Frontier, once in two years over Bengal and up to once in ten years over the Mysore plateau. Sind also begins to get an occasional hail-storm; at Kodaikanal in the south, the frequency is between one and two per year.

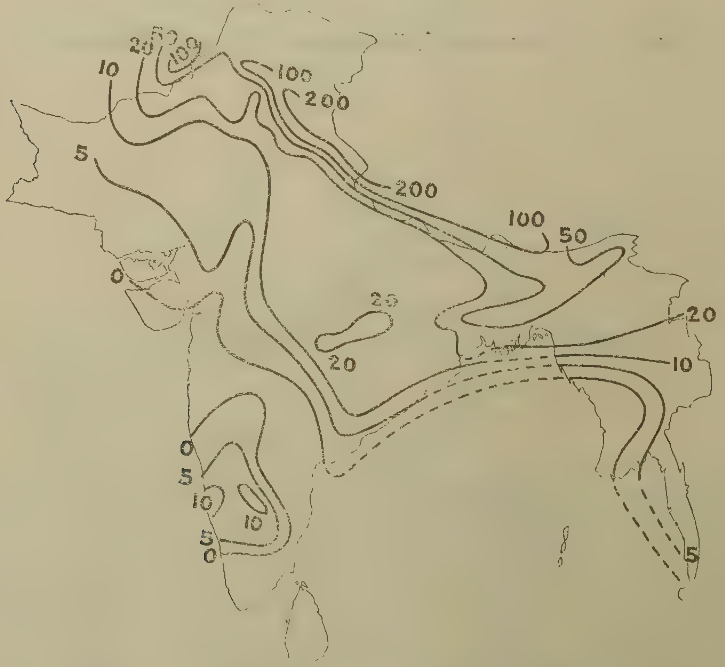


FIG. 5. Frequency of hail-storms in 100 years (April)

May (Fig. 6)

In May the area of high frequency of hail-storms in Bengal extends further southwards towards the Northern Circars, but conditions over the rest of the country are more or less as in April.

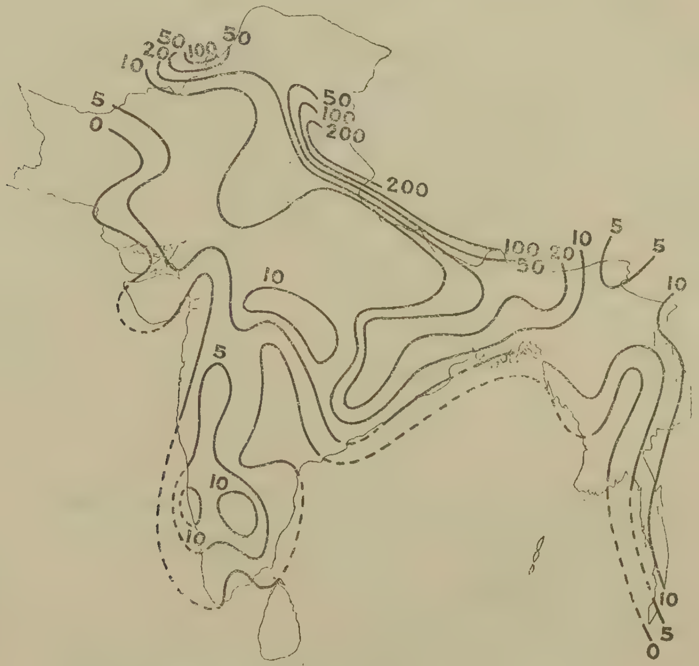


FIG. 6. Frequency of hail-storms in 100 years (May)

June (Fig. 7)

In June the monsoon winds set in and conditions begin to be less favourable for instability phenomena like thunder and hail-storms than in May. The decrease in the frequency of days with hail-storms is most marked over the Himalayan region, the frequency not exceeding once in two years even in the western Himalayas. The decrease over the plains is marked over Sind, Kathiawar, the Konkan and Burma where practically no hail-storms appear to occur in June.

July, August (Figs. 8 and 9)

In July and August the south-west monsoon is in full swing and there are hardly any hail-storms over the country except in the extreme north and over the North-West Frontier where the frequency does not exceed once in five years.

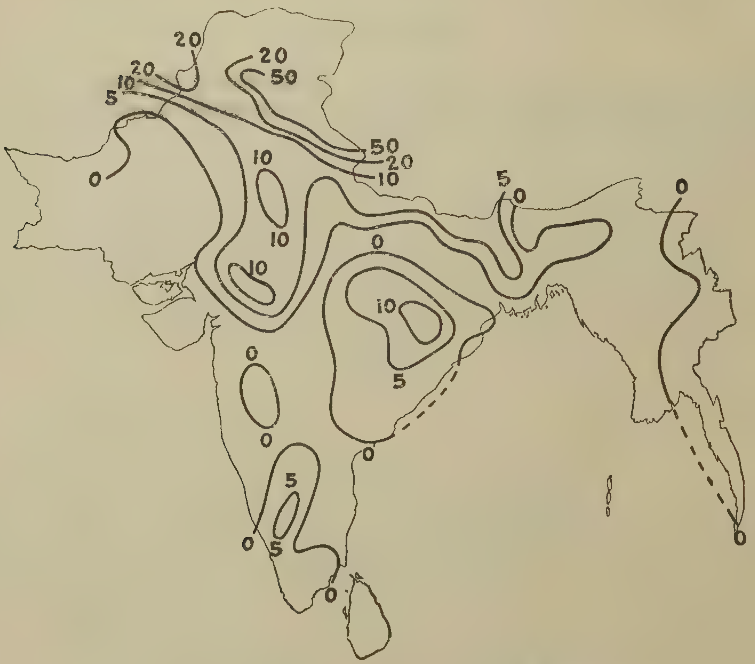

20
20
50
20
10
5
0
10
50
20
10
10
10
5
0
0
0
10
5
0
0
0
5
0
5
0
0

FIG. 7. Frequency of hail-storms in 100 years (June)

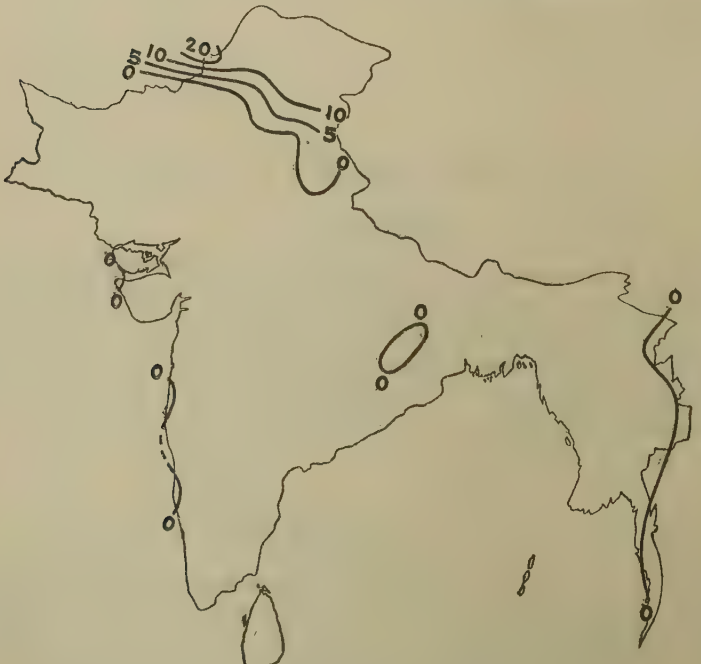

5
10
20
0
10
5
0
0
0
0
0
0
0
0
0

FIG. 8. Frequency of hail-storms in 100 years (July)

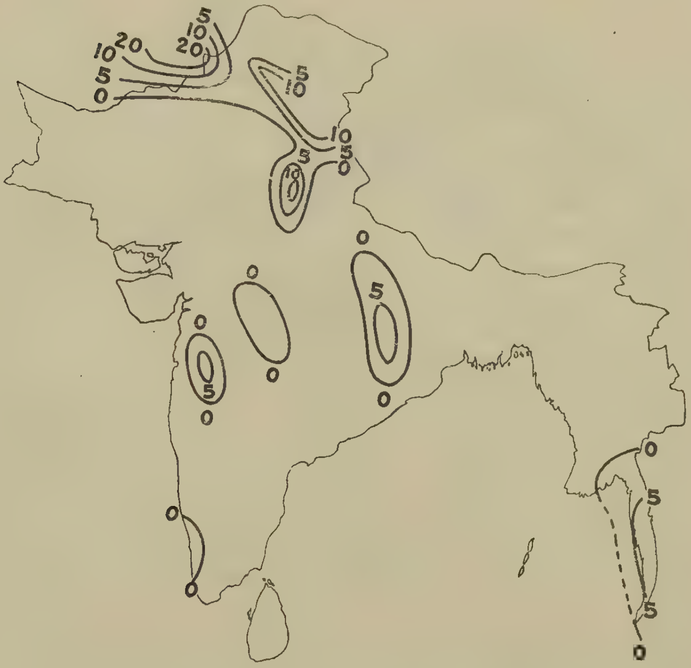


FIG. 9. Frequency of hail-storms in 100 years (August)

September, October (*Figs. 10 and 11*)

By the middle of September the south-west monsoon commences to retreat from north India and conditions become favourable again for an increase of hail-storms over the Himalayan region and its sub-montane tracts. The rest of India with the exception of Lower Burma and the Malabar Coast is generally free from the incidence of hail-storms.

November, December (*Figs. 12 and 13*)

In November and December wintry conditions set in ; besides the Himalayan region the central parts of the country also begin to get occasional hail-storms once in twenty years in November and once in ten years in December.

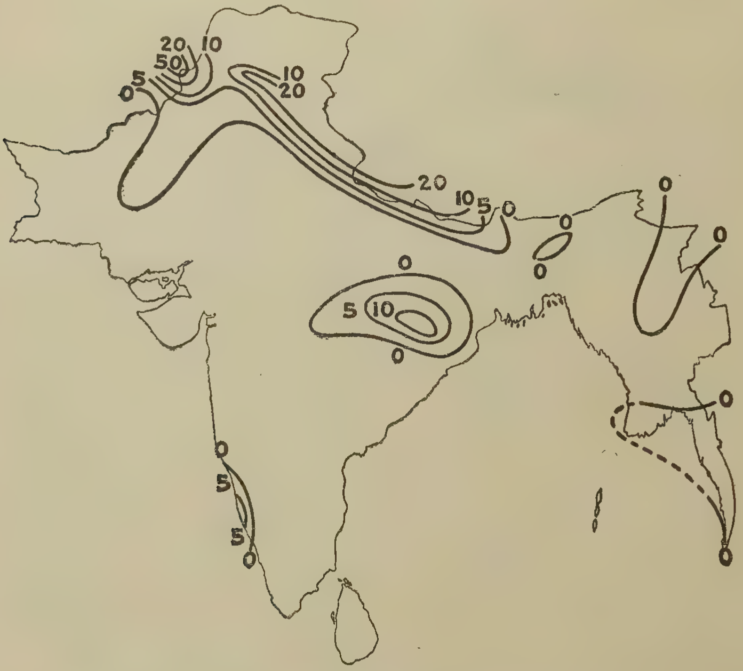

20
10
50
5
0
10
20
20
10
5
0
0
0
0
0
5
10
0
0
5
5
0
0
0

FIG. 10. Frequency of hail-storms in 100 years (September)

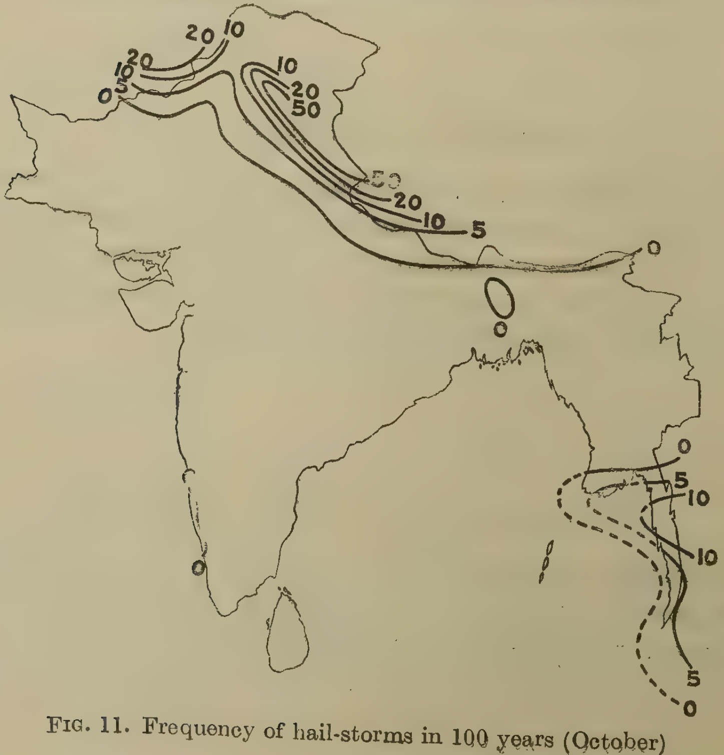

20
10
20
10
5
0
10
20
50
50
20
10
5
0
0
0
5
10
10
0
5
0

FIG. 11. Frequency of hail-storms in 100 years (October)

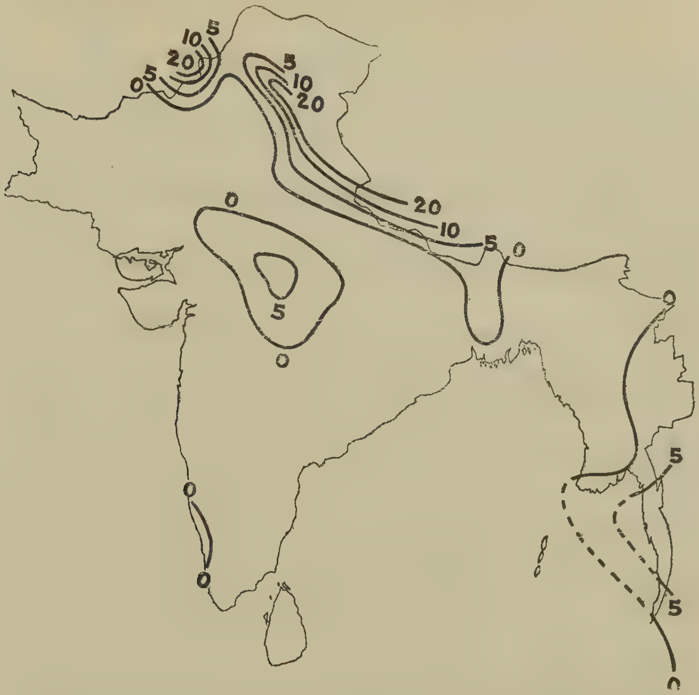

10
5
20
0
5
5
10
20
20
10
5
0
0
5
0
0
0
0
5
5
0

FIG. 12. Frequency of hail-storms in 100 years (November)

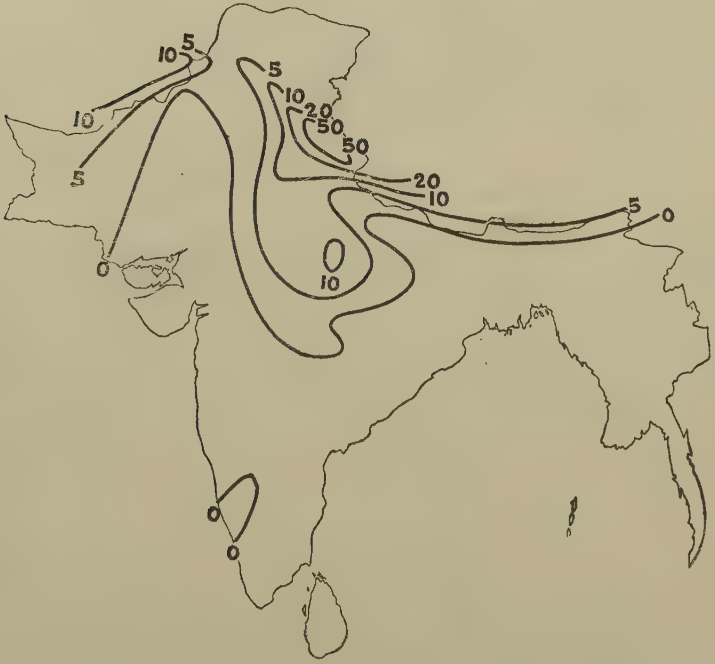

10
5
10
5
0
5
10
20
50
50
20
10
5
0
10
0
0

FIG. 13. Frequency of hail-storms in 100 years (December)

Annual frequency of hail-storms (Fig. 14)

Taking the year as a whole we find that the annual frequency is up to ten per year over the Western Himalayan region, and up to five per year over the Eastern Himalayan region and the mountainous tracts of the North-West Frontier ; this decreases rapidly to once in two years over the adjoining plains. Over Lower Bengal a hail-storm is usual once a year. The area consisting of the Central Provinces and the adjoining districts of Bihar and the United Provinces forms another centre of frequency of the order of once a year. The coastal tracts of the peninsula are regions where hail-storms are comparatively rare.

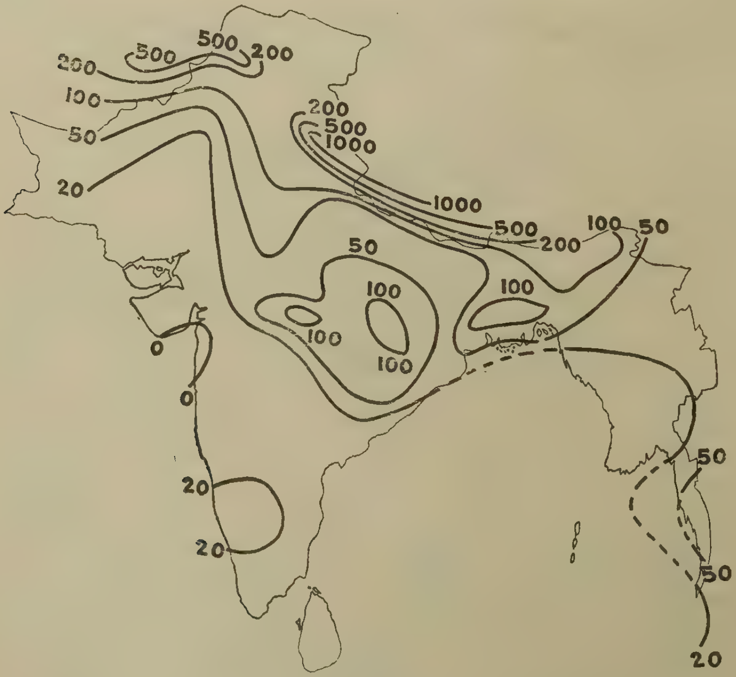

200
500
500
200
100
50
20
200
500
1000
1000
500
200
100
50
50
100
100
100
100
100
0
0
20
20
50
50
20

Fig. 14. Frequency of hail-storms in 100 years (annual)

While the maps and the brief descriptions of them given above are sufficient for getting an idea of the seasonal variation of the frequency of days with hail-storms over India, it is also necessary to study the results of Table 1, considering the different provinces or Indian states as the units. In Table II the mean frequencies of days with hail-storms over the different provinces and states are given for different months of the year. In arriving at the figures in Table II the frequencies of all the stations in each area have been added up and the total divided by the number of stations in the area. The different provinces or states have been arranged in Table II in the order of decreasing mean annual frequency of days with hail-storms. In this sequence Assam tops the list with a mean annual frequency of days with hail-storms of 100 in a century, or 1 per year, Kashmir, the North-West Frontier, the Punjab and Bengal, having frequencies of the order of 94, 91, 84 and 72 respectively in 100 years. The mean annual frequencies range between 51 and 70 in 100 years in Orissa and Chota Nagpur, Central India, the United Provinces and the Central Provinces. Baluchistan, Rajputana, Bihar, Mysore, Upper Burma and Malabar come in the third group of mean annual frequencies between twenty-one and fifty in 100 years, whereas Lower Burma, Berar, Sind, Bombay, Madras and Hyderabad are in the last group with mean annual frequencies between 0 and 20 in 100 years.

A careful study of Tables I and II also reveals certain interesting features regarding the seasonal distribution of frequency of days with hail-storms. Generally speaking, the year may be divided into two halves. The first half, January to June, includes most of the hail-storms during the year over the whole of India, whereas the second half, July to December (the first portion of which, *viz.*, July-September, covers the monsoon period), has very few occasions of hail-storms. The general increase of frequency during the pre-monsoon period culminating in a maximum frequency in April is well shown by the totals at the bottom of Table II.

CONCLUSION

From the foregoing sections it is clear that the phenomenon of hail should be regarded as a risk to agriculture, to which the methods of insurance may be applied for safeguarding the interests of the farmer by insuring his crops against hail-damage.

In conclusion we wish to express our best thanks to Dr. C. W. B. Normand, C.I.E., M.A., D.Sc., Director-General of Observatories, Meteorological Office, Poona, for the facilities given for conducting this investigation.

TABLE I

Frequency of days with hail-storms (number of occasions in 100 years)

Station	No. of years of data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
							Lower Burma							
Victoria Point	25-26	4	...	...	...	...	...	...	...	4	4	...	4	16
Tavoy .	38	...	...	21	8	11	5	3	5	3	11	8	...	75
Rangoon .	38	...	...	...	5	3	...	...	3	...	...	...	...	11
Bassein .	38	...	...	...	...	...	...	...	...	3	...	...	...	3
Diamond Island	38	...	...	...	...	...	...	...	...	...	5	3	...	8
Toungoo .	38	...	...	3	...	3	3	...	...	...	...	...	...	9
Kyaukpyu .	27-28	...	...	...	4	4	7	...	...	4	...	...	...	19
Akyab .	38	...	...	3	...	3	...	...	...	...	...	...	...	6
							Upper Burma							
Minbu .	38	...	...	...	...	5	...	...	...	...	...	...	...	5
Yamethin .	38	...	...	3	3	...	...	...	...	...	...	...	...	6
Mandalay .	38	...	3	...	13	...	...	...	...	3	...	...	5	24
Lashio .	38	...	...	5	16	5	...	...	...	...	...	3	...	29
Bhamo .	38	8	5	3	24	13	5	3	...	5	...	...	...	66
Myitkyina .	32-33	...	3	9	3	...	...	...	...	...	...	...	...	15
							Assam							
Dibrugarh .	34-35	9	9	27	23	...	6	...	...	...	3	...	6	82
Sibsagar .	38	3	21	39	47	3	...	...	...	...	...	...	...	113
Tezpur .	34-35	3	3	12	27	12	...	...	...	...	...	...	...	57
Gauhati .	33-34	...	18	42	70	27	...	3	...	...	...	...	...	160
Silchar. .	38	...	5	21	42	8	3	...	...	...	...	3	...	82
							Bengal							
Cox's Bazar .	27-28	...	...	4	4	...	...	...	...	...	...	...	...	8
Chittagong .	38	3	11	8	24	5	...	...	3	...	...	...	...	54
Narayanganj	38	...	5	39	63	11	...	...	...	...	...	...	...	118
Barisal .	38	...	...	18	24	5	...	...	...	...	...	...	...	47
Jessore .	38	3	8	24	53	18	3	...	...	...	...	...	...	109
Calcutta .	38	...	5	18	37	3	...	...	...	...	...	...	...	63
Saugor Island	38	3	5	3	8	3	...	...	...	...	...	...	...	22
Burdwan .	38	3	11	18	58	26	...	...	3	...	...	...	...	119
Berhampore	38	...	16	18	39	29	11	...	...	...	...	3	...	116
Mymensingh.	38	3	...	11	21	13	3	...	...	3	...	...	...	54
Bogra . .	38	...	...	16	29	16	...	...	...	...	3	...	...	64
Dinajpur .	38	...	3	8	39	29	...	...	...	...	3	3	...	85
Jalpaiguri .	38	3	5	3	37	24	...	...	...	...	...	...	...	72

TABLE I—*contd.*

Station	No. of years of data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Orissa and Chota Nagpur														
Balasore	38	5	5	34	34	8	3	...	...	...	...	...	...	89
Cuttack	38	3	...	8	8	8	...	...	...	...	...	...	...	27
Sambalpur	38	5	11	3	18	16	13	3	5	13	3	...	...	90
Chaibasa	38	...	3	...	3	13	...	...	...	...	...	...	...	19
Ranchi	38	11	13	13	16	32	...	3	...	3	...	...	...	91
Bihar														
Purnea	38	...	5	...	18	11	3	...	...	3	...	...	...	40
Patna	38	11	8	5	13	5	...	...	...	...	...	...	...	42
Gaya	38	3	5	3	5	11	...	...	...	...	...	...	...	27
Naya Dumka	38	...	...	3	11	11	...	...	...	...	...	...	...	25
United Provinces														
Gorakhpur	38	11	...	13	3	5	...	...	...	...	3	...	...	35
Benares	38	5	21	8	...	3	...	...	3	...	...	...	5	45
Allahabad	38	11	26	11	8	8	...	...	3	...	...	...	3	70
Lucknow	38	5	11	8	5	3	5	...	...	...	...	...	...	37
Jhansi	38	...	13	8	5	3	3	3	...	...	...	3	5	43
Agra	38	...	16	11	3	5	3	...	...	...	3	...	5	46
Bareilly	38	8	5	11	11	5	3	...	...	...	5	...	3	51
Roorkee	38	26	24	29	11	...	5	3	...	...	3	3	16	120
Punjab														
Delhi	38	11	24	16	13	11	5	...	13	...	...	...	3	96
Hissar	21-22	14	9	29	9	18	9	...	...	...	...	...	14	102
Ambala	38	5	21	34	26	8	3	...	...	...	3	5	8	113
Ludhiana	38	5	5	13	5	5	3	...	...	...	5	...	...	41
Lahore	38	8	11	13	21	11	18	3	...	...	8	...	3	96
Sialkot	38	11	13	11	13	3	...	...	3	3	8	3	3	71
Rawalpindi	38	13	32	24	26	16	11	11	...	5	3	3	3	147
Khushab	38	3	11	18	13	5	13	...	3	3	5	3	3	80
Lyallpur	22-23	14	14	23	26	9	4	...	...	...	4	...	4	98
Montgomery	38	11	16	8	8	8	3	...	...	...	3	...	3	60
Multan	38	3	...	3	5	3	3	...	...	...	...	...	...	17

TABLE I—*contd.*

Station	No. of years of data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Kashmir														
Srinagar .	38	...	3	13	29	26	13	...	5	5	...	...	...	94
North-West Frontier Province														
Peshawar .	38	8	13	37	50	13	...	3	...	11	8	3	...	146
Dera Ismail Khan	38	...	5	11	8	3	3	...	...	3	...	3	...	36
Baluchistan														
Fort Sandeman.	23-24	...	4	17	21	13	...	...	...	...	4	...	...	59
Quetta. .	38	8	...	11	18	8	3	...	...	...	...	...	3	51
Chaman .	38	...	5	13	11	...	...	...	...	...	...	...	8	37
Sind														
Jacobabad .	38	...	...	...	5	...	...	...	3	3	...	...	...	11
Hyderabad .	38	...	...	...	3	8	...	...	...	...	...	...	...	11
Karachi .	38	...	...	5	3	...	...	...	...	...	...	...	3	11
Rajputana														
Bikaner .	38	3	3	...	8	13	5	...	...	...	...	...	...	32
Jodhpur .	38	...	3	...	8	13	...	...	...	...	...	3	...	27
Jaipur .	38	5	13	13	13	11	13	...	...	...	...	...	8	76
Ajmer . .	38	3	5	13	3	8	3	...	...	...	...	...	3	38
Kotah . .	38	3	3	5	16	8	5	...	...	...	...	5	5	50
Central India														
Neemuch .	38	...	13	8	3	8	3	...	...	...	...	...	...	35
Indore .	38	8	13	3	5	24	13	...	3	...	...	...	3	72
Nowgong .	38	16	21	8	11	8	...	...	...	...	3	3	11	81
Sutna . .	38	13	8	5	3	3	5	...	...	...	...	...	3	40
Berar														
Akola . .	38	3	...	5	3	...	...	...	...	...	...	...	...	11
Amraoti .	38	...	3	...	5	3	...	...	3	...	...	...	3	17

TABLE I—*contd.*

Station	No. of years of data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Central Provinces														
Khandwa	38	3	...	...	8	5	...	...	...	...	...	...	...	16
Saugor	38	3	13	8	3	3	...	...	...	...	...	3	5	38
Jubbulpore	38	13	26	13	8	8	5	...	...	...	...	...	5	78
Seoni	38	...	3	13	8	13	...	...	...	3	...	...	...	40
Nagpur	38	3	18	18	21	16	3	...	...	...	...	...	3	82
Pendra	32-33	16	16	31	25	22	6	...	...	6	...	...	...	122
Raipur	38	3	5	13	13	5	3	...	...	...	...	...	...	42
Chanda	38	...	8	...	13	5	...	...	...	...	...	...	...	26
Jagdalpur (Bastar)	26-27	...	8	4	15	23	4	...	...	...	...	...	4	58
Bombay														
Deesa	38	...	...	...	3	5	...	...	...	...	...	...	...	8
Bhuj	38	...	...	...	5	...	...	...	...	...	...	...	...	5
Dwarka	35	...	...	...	...	...	3	3	...	...	...	...	...	6
Rajkot	38	...	...	3	3	3	...	...	...	...	...	3	...	12
Veraval	38	...	...	...	...	3	...	...	...	...	...	...	...	3
Surat	38	...	...	...	...	...	...	...	...	...	...	...	...	...
Ahmedabad	38	...	...	3	3	...	...	...	...	...	...	...	...	6
Bombay	38	...	...	...	...	...	...	...	...	...	...	...	...	...
Ratnagiri	38	...	...	3	...	...	...	3	3	...	...	...	...	9
Karwar	38	...	...	...	3	...	...	...	...	...	...	...	...	3
Malegaon	38	...	...	...	3	3	...	...	...	...	...	...	...	6
Ahmadnagar	38	...	3	...	...	5	3	...	5	...	...	3	3	22
Sholapur	38	...	...	...	3	5	3	...	...	...	...	...	...	11
Bijapur	38	...	...	...	3	3	...	...	...	...	...	...	...	6
Hyderabad														
Aurangabad	38	3	3	3	...	3	...	...	...	...	...	...	...	12
Nizamabad	38	...	...	...	3	...	...	...	...	...	...	...	...	3
Gulbarga	38	...	...	3	3	3	...	...	...	...	...	...	...	9
Raichur	38	...	3	...	...	...	...	...	...	...	...	...	...	3
Hanamkonda	38	...	...	...	...	...	3	...	...	...	...	...	...	3
Mysore														
Chitaldrug	38	...	3	...	8	8	3	...	...	...	...	...	3	25
Bangalore	38	...	...	3	16	16	...	...	...	...	3	...	...	38
Mysore	38	...	...	5	8	13	5	...	...	...	...	...	...	31

TABLE I—*concld.*

Station.	No. of years of data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Malabar														
Mangalore	38	...	...	3	13	16	...	3	...	8	5	...	...	48
Calicut	38	5	...	...	5	8	3	...	3	...	3	3	...	30
Cochin	38	...	...	...	...	...	3	...	...	...	...	...	...	3
Trivandrum	38	3	...	...	...	3	3	...	...	...	...	...	...	9
Madras														
Pamban	38	...	...	...	...	...	...	...	...	...	...	...	...	...
Madura	38	...	3	...	...	...	...	...	...	...	...	...	...	3
Negapatam	38	...	...	...	...	3	...	...	...	...	...	...	...	3
Trichinopoly	38	...	...	...	...	5	3	...	...	...	...	...	...	8
Coimbatore	38	...	...	3	...	...	...	...	...	...	...	...	...	3
Salem	38	...	...	...	8	10	...	...	...	...	...	...	...	18
Vellore	35-36	...	...	...	...	3	...	...	...	...	...	...	...	3
Cuddapah	38	...	...	...	...	3	...	...	...	...	...	...	...	3
Bellary	38	...	...	5	...	...	3	...	...	...	...	...	...	8
Kurnool	38	...	...	...	...	...	...	...	...	...	...	...	...	...
Nellore	38	...	...	...	...	3	...	...	...	...	...	...	...	3
Masulipatam	38	...	...	...	3	3	...	...	...	...	...	...	...	6
Cocanada	38	...	...	3	...	8	3	...	...	...	...	...	...	14
Gopalpur	38	...	...	3	5	3	3	...	...	...	...	...	...	14
Hill stations, excluding Kashmir and Baluchistan														
Shillong	33-34	...	9	36	55	24	...	...	...	3	...	...	...	127
Cherrapunji	33-34	...	18	64	127	76	6	3	...	...	3	3	...	300
Darjeeling	38	3	26	95	105	89	5	...	...	...	3	3	5	334
Mukteswar	29	48	117	224	217	245	65	3	...	17	62	24	31	1,055
Simla	38	68	108	229	211	208	63	3	5	18	58	45	58	1,074
Murree	38	24	66	108	124	105	50	5	18	29	79	26	16	650
Cherat	38	18	24	32	37	37	11	8	3	11	...	...	11	192
Parachinar	27	11	33	41	115	100	48	37	33	93	22	26	11	571
Mount Abu	38	8	11	3	8	5	5	3	...	5	3	...	3	54
Pachmarhi	38	13	37	24	18	5	11	...	...	...	...	3	3	114
Mercara	38	5	...	3	8	...	...	...	...	...	...	...	3	19
Kodaikanal	36-37	...	6	33	164	147	22	3	...	8	8	3	...	394

TABLE II

Mean frequency of days with hail-storms over various areas in India

(The figures represent number of occasions in 100 years)

Name of area	No. of stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
71—100														
Assam	5	3	11	28	42	10	2	1	0	0	1	1	1	100
Kashmir	1	0	3	13	29	26	13	0	5	5	0	0	0	94
N.-W. F. Province	2	4	9	24	29	8	2	1	0	7	4	3	0	91
Punjab	11	9	14	17	15	9	7	1	2	1	4	1	4	84
Bengal	13	1	5	15	33	14	1	0	0·5	0	0·5	0·5	0	71
51—70														
Orissa & Chota Nagpur	5	5	6	12	15	15	3	1	1	3	1	0	0	62
Central India	4	9	14	6	6	11	5	0	1	0	1	1	4	58
United Provinces	8	8	15	12	6	4	2	1	1	0	1	1	5	56
Central Provinces	9	5	11	11	13	11	2	0	0	1	0	0	2	56
21—50														
Baluchistan	3	3	3	14	17	7	1	0	0	0	1	0	4	50
Rajputana	5	3	5	6	10	11	5	0	0	0	0	2	3	45
Bihar	4	3	5	3	12	10	1	0	0	1	0	0	0	35
Mysore	3	0	1	3	11	12	3	0	0	0	1	0	1	32
Upper Burma	6	1	2	3	10	4	1	0·5	0	1	0	0·5	1	24
Malabar	4	2	0	1	5	7	2	1	1	2	2	1	0	24
0—20														
Lower Burma	8	0·5	0	3	2	3	2	0	1	2	2·5	1	0·5	17
Berar	2	1·5	1·5	2·5	4	1·5	0	0	1·5	0	0	0	1·5	14
Sind	3	0	0	2	4	3	0	0	1	1	0	0	1	12
Bombay	14	0	0	1	2	2	1	0	1	0	0	0	0	7
Madras	14	0	0	1	1	2	1	0	0	0	0	0	0	5
Hyderabad	5	1	1	1	1	1	0	0	0	0	0	0	0	5
Total	...	59	106	179	267	171	54	7	16	24	19	12	28	942

STUDIES ON QUALITY IN RICE

II. CHEMICAL COMPOSITION OF RICE VARIETIES

BY

V. SADASIVAN, B.Sc. (Agric.)

AND

A. SREENIVASAN, M.A., D.Sc., A.I.C.

Department of Biochemistry, Indian Institute of Science, Bangalore

(Received for publication on 13th July 1938)

The importance of a chemical study of a valuable food crop such as rice has been universally recognised and a number of enquiries have been directed towards the examination of different varieties of rice all over the world. Mention may be made of the analyses by Church [1886], Leather [1903], Hooper [1908-09], Warth and Darabsett [1913], Sen [1916], MacCarrison and Norris [1924], Joachim and Kandiah [1928] and Basu and Sarkar [1935] in India, Burma and Ceylon; Kellner [1889], Kellner and Nagaoka [1892], Takahashi and Sato [1913] and others in Japan; Ross [1889], Brown and Chiquelin [1904], Thompson [1915], Wise and Broomell [1916], Fraps [1916] and Kennedy [1924] and others in America; and Balland [1895], Krauss *et al.* [1907], Aron and Hocson [1911], Borassio [1930] and others in France, Italy and other countries.

A few workers have also studied the effect of polishing on the composition of the kernel [Sreenivasan *et al.*, 1938]; very little information is, however, available regarding the composition of different varieties of rice including (1) coarse and fine varieties, (2) coloured and white rices, (3) long and short duration crops, (4) 'dry' and 'wet' cultivated rices and (5) hard, soft and glutinous rices [Sreenivasan and Subrahmanyan, 1935]. The coarse-grained and early varieties of rices are mainly consumed by the poorer classes of people, while the rich people generally use the finer and late varieties of rice, which are considered superior. It is also held that the coloured rices are more nutritious than the ordinary white rices. Scientific evidence in regard to the comparative nutritive qualities and chemical composition of different classes of rice grains is, however, not available.

In the present paper are reported the analyses of different varieties of rice and the changes in the composition of husked (unpolished) rice grain as a result of (*a*) polishing, (*b*) parboiling and (*c*) parboiling and polishing.

EXPERIMENTAL

The work has been confined to samples of rice—most of them pure strains—grown in the various Government Agricultural Research Stations of the Madras Presidency*.

Parboiling, husking and polishing were all done in the manner outlined previously [Sreenivasan *et al.*, 1938]. Moisture, fat, ash, protein and phosphorus were determined by methods described earlier, while crude fibre and calcium were estimated according to methods of the A. O. A. C. [1935]. The acrbohydrate contents were determined by difference and the vitamin B_1 estimated colorimetrically by the Spruyt method as modified by Acton, Ghosh and Dutt [1933].

The experimental results have been summarised in Tables I—V. Table I (*a* and *b*) gives the description and characteristics of the different varieties of rice. In Table II are recorded the composition of the husked, unpolished rices. The changes in composition as a result of polishing have been presented in Table III. Polishing in every case was done till a white grain, free from any adhering bran layers, was obtained in every case. The degree of polishing of the samples, which thus gives an indication of thickness of bran layer, has been included in Table III. Table IV gives the results of analyses of some of the samples of rice, both unpolished and polished, after parboiling. An analysis of some well-known bazaar specimens of (milled) rices, both raw and parboiled, are given in Table V.

---

*Grateful acknowledgment is made to the Government Paddy Specialist at Coimbatore, Madras, for the supply of these samples and for a descriptive account of their characteristics.

TABLE I (*a*)

Description and characteristics of rice varieties

Variety	Grain shape	Length in mm.	Breadth in mm.	Thickness in mm.	Thickness of hull in mm.	Acre yield in lbs.
Co 9	Elliptic	7·5	3·2	2·2	0·16	3000
Adt 3	Do.	7·8	3·2	2·2	0·17	2000
Adt 7	Do.	7·9	3·1	2·0	0·17	1400
T 134	Oblong	9·0	3·2	2·0	0·20	..
Co 5	Elliptic	7·8	2·6	1·9	0·15	4700
T 111	Do.	9·5	2·1	1·8	0·14	..
T 167	Do.	8·4	2·5	1·9	0·17	..
T 304	Oblong	10·3	2·9	2·0	0·16	1530
T 149	Elliptic	8·5	2·8	2·0	0·16	..
T 356	Do.	8·9	2·3	1·8	0·13	..
Co 1	Do.	8·7	2·7	2·0	0·15	3600
T 59	Do.	7·9	2·2	1·8	0·17	..
T 150	Oblong	8·7	3·4	2·3	0·15	..
T 523	Ovate	7·3	3·3	2·2	0·16	..
Co 10	Oblong	8·4	3·1	2·1	0·15	2500
GEB 24	Elliptic	7·6	2·3	1·7	0·13	3500
Co 7	Do.	8·1	2·6	1·9	0·20	4700
Adt 11	Do.	8·3	2·8	2·0	0·15	2500
Kattamodan	Oblong	8·5	3·3	2·1	0·17	506
Dirtymodan	Elliptic	8·0	3·3	2·1	0·17	1033
Blackmodan	Do.	8·8	3·1	2·2	0·18	555
Chennellu	Oblong	8·5	3·3	2·1	0·23	615

TABLE I (*b*)

Description and characteristics of rice varieties—contd.

Variety	Grain size	Wt. of 100 grains grm.	Colour of grain	Duration of crop (days)	Nature of rice
Co 9 .	Coarse .	2·00	Red .	123	Medium-soft
Adt 3 .	Medium .	1·79	White .	104	Do.
Adt 7 .	Do. .	1·89	Do. .	237	Do.
T 134 .	Coarse .	2·22	Purple .	162	Soft
Co 5 .	Medium-fine	1·52	White .	167	Hard
T 111 .	Fine . .	1·49	Red .	157	Do.
T 167 .	Medium .	1·67	White .	191	Do.
T 304 .	Coarse .	2·20	Do. .	164	Glutinous
T 149 .	Medium .	1·65	Golden .	160	Hard
T 356 .	Fine . .	1·52	Light red .	157	Do.
Co 1 .	Medium-fine	1·72	White .	151	Do.
T 59 .	Fine . .	1·32	Brown .	159	Do.
T 150 .	Coarse .	2·28	Light red .	159	Soft
T 523 .	Medium .	1·82	White .	191	Do.
Co 10 .	Coarse .	2·70	Do. .	119	Do.
GEB 24 .	Fine . .	1·42	Do. .	140	Hard
Co 7 .	Medium .	1·57	Do. .	158	Do.
Adt 11 .	Do. .	1·65	Do. .	172	Do.
Kattamodan .	Coarse .	2·17	Red .	..	Medium-soft
Dirtymodan .	Do. .	..	Do. .	..	Do.
Blackmodan .	Do. .	..	Do. .	..	Do.
Chennellu .	Do. .	1·68	Do. .	..	Soft

TABLE II

Composition of rice varieties—raw, unpolished

Variety	Percentages								Vitamin B_1 index
	Moisture	Crude protein	Ether extract	Crude fibre	Carbo-hydrates	Ash	P_2O_5	CaO	
Co 9	12·2	8·42	2·20	0·45	75·1	1·55	0·64	0·09	149
Adt 3	11·8	9·23	2·60	0·58	74·4	1·43	0·72	0·11	170
Adt 7	12·4	6·36	1·97	0·27	77·5	1·49	0·49	0·11	137
T 134	10·3	8·12	2·30	0·46	77·4	1·41	0·39	0·06	345
Co 5	10·9	5·93	2·20	0·63	79·0	1·38	1·15	0·10	196
T 111	9·6	7·18	2·50	0·31	79·2	1·23	1·02	0·12	286
T 167	10·3	6·29	2·80	0·56	78·6	1·43	0·70	0·90	179
T 304	10·1	6·43	3·00	0·48	78·7	1·32	1·05	0·06	189
T 149	10·2	7·93	2·70	0·37	77·4	1·44	1·00	0·06	222
T 356	9·6	7·98	2·52	0·49	78·2	1·24	0·56	0·06	172
Co 1	11·0	6·23	2·46	0·49	78·4	1·40	0·86	0·05	159
T 59	11·5	7·31	2·36	0·71	77·0	1·10	0·52	0·07	200
T 150	10·9	6·65	2·36	0·59	77·9	1·57	1·19	0·09	204
T 523	11·4	6·34	2·67	0·45	77·8	1·35	0·75	0·05	102
Co 10	12·1	6·69	2·17	0·72	76·9	1·45	0·69	0·05	124
GEB 24	10·6	6·23	2·46	0·62	78·6	1·48	0·48	0·06	112
Co 7	9·2	5·92	2·32	0·67	80·3	1·54	1·27	0·08	76
Adt 11	12·4	5·77	2·28	0·56	77·7	1·28	0·61	0·08	313
Kattamodan	9·8	5·46	2·25	0·38	81·1	1·02	0·47	0·09	250
Dirtymodan	11·4	5·61	2·07	0·76	79·0	1·16	0·65	0·05	84
Blackmodan	11·6	5·38	2·15	0·66	78·9	1·25	0·63	0·02	118
Chennellu	11·4	4·77	2·02	0·66	79·8	1·34	0·56	0·05	192
Average	10·9	6·05	2·38	0·54	77·4	1·36	0·75	0·07	...

TABLE III

Composition of rice varieties—raw, polished

Variety	Degree of polishing (per cent)	Percentages								Vitamin B_1 index
		Moisture	Crude protein	Ether extract	Crude fibre	Carbo-hydrates	Ash	P_2O_5	CaO	
Co 9	13·5	12·3	6·71	0·67	0·26	79·6	0·51	0·45	0·04	106
Adt 8	17·3	12·1	6·03	0·70	0·28	80·4	0·50	0·33	0·06	128
Adt 7	19·6	12·1	5·63	0·36	0·26	81·1	0·57	0·28	0·04	118
T 134	24·6	10·8	6·96	0·28	0·24	81·4	0·40	0·23	0·03	182
Co 5	18·4	11·0	4·95	0·35	0·18	83·1	0·47	0·29	0·04	178
T 111	20·2	11·9	5·89	0·32	0·22	81·4	0·31	0·13	0·05	238
T 167	22·1	12·2	5·34	0·75	0·26	80·9	0·52	0·25	0·03	141
T 304	28·1	11·3	5·40	0·66	0·23	82·0	0·38	0·25	0·04	...
T 149	19·2	11·5	6·63	0·43	0·27	80·7	0·52	0·37	0·02	154
T 356	14·7	11·7	6·76	0·46	0·14	80·5	0·43	0·36	0·02	145
Co 1	10·3	11·8	6·00	0·91	0·20	80·4	0·71	0·31	0·03	132
T 59	12·2	11·4	6·61	0·83	0·23	80·5	0·47	0·34	0·05	152
T 150	28·1	11·5	5·31	0·43	0·13	82·1	0·52	0·23	0·04	159
T 523	9·7	11·8	5·77	1·06	0·22	80·5	0·66	0·48	0·03	99
Co 10	18·1	12·0	6·00	0·39	0·22	80·9	0·53	0·26	0·03	111
GEB 24	10·6	12·3	5·38	0·74	0·25	80·7	0·60	0·28	0·04	83
Co 7	9·7	11·0	5·50	0·64	0·27	82·0	0·64	0·25	0·05	...
Adt 11	13·1	12·5	5·19	0·58	0·23	81·0	0·56	0·31	0·04	185
Kattamodan	18·7	11·6	4·31	0·34	0·24	83·3	0·24	0·12	0·02	74
Dirtymodan	22·2	11·0	4·96	0·48	0·26	82·9	0·40	0·24	0·01	62
Blackmodan	22·9	11·6	4·62	0·43	0·23	82·8	0·38	0·22	0·01	...
Chennellu	18·1	10·8	4·23	0·45	0·17	83·9	0·44	0·24	0·02	159
Average	17·8	11·6	5·65	0·56	0·23	81·5	0·49	0·28	0·03	...

TABLE IV

Composition of rice varieties—parboiled, unpolished and polished

Variety	Unpolished Percentages				Per cent polished	Polished Percentages			
	Moisture	Crude protein	Ash	P_2O_5		Moisture	Crude protein	Ash	P_2O_5
Co 10	11·3	6·69	1·48	0·65	18·1	10·0	5·82	0·54	0·26
Adt 3	10·7	9·20	1·55	0·69	17·3	10·9	6·23	0·52	0·33
Co 5	10·7	5·87	1·36	...	18·5	10·4	4·98	0·43	0·27
Adt 7	9·7	6·30	1·48	0·49	19·6	10·1	5·59	0·55	0·32
Co 1	10·6	6·22	1·50	0·86	10·3	10·4	6·00	0·72	0·31
T 111	10·7	7·01	1·23	1·00	20·2	10·0	5·90	0·30	0·14
T 59	11·9	7·32	1·03	0·47	12·2	10·2	6·61	0·43	0·36
Dirtymodan	11·0	5·60	1·37	0·67	22·2	11·2	5·00	0·41	0·26
T 304	11·5	6·48	1·37	0·70	28·1	10·2	5·36	0·35	0·23
T 167	8·5	6·20	1·47	0·70	22·1	10·6	5·42	0·54	0·29
T 523	8·6	6·34	1·46	0·74	9·7	9·7	6·12	0·60	0·52
GEB 24	9·3	6·12	1·48	0·47	10·6	9·2	5·14	0·55	0·28
Average	10·4	6·61	1·40	0·62	17·4	10·2	5·68	0·50	0·30

TABLE V

Composition of bazaar samples of rice—raw and parboiled (milled)

Raw					Parboiled				
Sample No.	Moisture	Crude protein	Ash	P_2O_5	Sample No.	Moisture	Crude protein	Ash	P_2O_5
				Percentages					
I	12·6	5·06	0·61	0·26	I	13·4	5·22	0·72	0·28
II	13·3	5·79	0·74	0·31	II	13·6	5·72	0·64	0·31
III	12·0	5·50	0·62	0·27	III	12·8	6·36	0·78	0·34
IV	12·3	5·99	0·59	0·23	IV	12·8	6·28	0·81	0·25
V	11·8	5·64	0·47	0·22	V	12·0	6·04	0·92	0·48
VI	12·7	5·91	0·58	0·18	VI	12·7	6·44	0·72	0·29
VII	14·3	5·42	1·01	0·30	VII	14·1	6·08	0·74	0·28
VIII	13·2	5·65	0·43	0·20	VIII	13·1	5·96	0·82	0·39
IX	13·5	6·48	0·64	0·29	IX	13·7	5·22	1·20	0·43
X	14·0	5·71	0·75	0·29	X	13·0	6·16	0·76	0·42
Average	13·0	5·22	0·64	0·26		13·1	5·95	0·81	0·35

Discussion of results

It may be observed from Table II that when the average values for the different constituents are compared with those obtained by previous investigators, there is not very much difference in the composition of rice. There is, however, a large variation in composition between the individual varieties.

The composition of polished rice (Table III) is dependent somewhat on that of the original rice, though the change in composition as a result of polishing is essentially similar to that recorded by previous workers [Sen, 1916 ; Basu and Sarkar, 1935]. The polished rice becomes poorer in all the constituents except carbohydrates. The amounts of ether extractives and proteins decrease to less than 30 per cent, the fibre content is reduced to about 20 per cent, while the amounts of mineral constituents fall off to half, phosphorus alone being lost by more than 80 per cent. A large part of the essential nutritive constituents are therefore localised in the exterior layers, *viz.*, bran and embryo.

It is interesting to note that with the exception of the Modan varieties, the coloured and coarser rices generally seem to contain larger amounts of proteins and mineral matter, particularly phosphorus and calcium. Such varieties also required greater amount of polishing than the finer types for producing white grains. The coarser type of rices generally do not possess good milling qualities [Sreenivasan *et al.*, 1938]. Under ordinary conditions of milling, the extent of loss of essential constituents from coloured or coarse varieties is therefore less than that from superior types. That coloured and coarse varieties have thicker bran layers has also been indicated by histological examination of rice varieties carried out at Coimbatore [Ramiah, 1936]. Kennedy [1924] has stated that wild rices have more food value than cultivated (fine) rices, the proteins being of better quality and the content of vitamin B greater.

Parboiling does not bring in any appreciable change in the composition of unpolished rices (Table IV). Parboiled polished rices are also not very different in composition from the corresponding raw rices polished to the same degree [Sreenivasan *et al.*, 1938]. The results of analyses of commercial samples of rice, both raw and parboiled (Table V), however, show that parboiled (polished) rice is somewhat richer in proteins and minerals than raw (polished) rice. This is because, in commercial practice, the long-grained and coloured varieties (which are generally classed as inferior) are used for parboiling. These have invariably thick bran layers and contain more nitrogen and phosphorus than the white and small-grained varieties [Sreenivasan and Das Gupta, 1936]. Again, since parboiling yields a coloured product, even after some polishing and is largely consumed (at any rate in many provinces of India) by the poorer classes, it is not generally polished to the same extent as raw rice. These two causes are perhaps primarily responsible for the richness of commercial samples of parboiled rices in regard to both nitrogen and phosphorus as compared with raw samples of rice.

In feeding experiments on animals (unpublished data) it has been found that, given adequate supply of the antineuritic vitamin, the growth-promoting factors of different varieties of rices are related to their nitrogen and mineral (phosphorus) contents ; and there is no doubt that, other things being equal, the variety of rice which contains larger amounts of protein and mineral constituents is more valuable. It would therefore follow that shelled (unpolished) rices—especially from coloured varieties—are the most satisfactory. Such rices, however, cannot be kept for long periods ; they rapidly become rancid and get readily attacked by insects. A method of overcoming this difficulty is to shell the required quantity from time to time in wooden hand-hullers.

Unpolished rices, on account of thick bran layers, are rather slow to cook, but this defect is more than compensated by the bigger return of shelled rice. The present system of milling yields only 50 to 60 per cent by volume of head rice (the percentage depending on the variety) whereas if only hulling is resorted to, the yield may rise to over 70 to 80 per cent. In this manner the consumer will stand to gain not only in quantity of available food material but also in quality.

Improvements in the quality of rice should be made along the lines of increasing the protein and mineral contents of the grain. This should seem possible by judicious control of fertiliser applications as has been shown with wheat and barley by recent investigators. The chemical composition of rice kernel is greatly influenced by several factors, *viz.*, climatic conditions during plant growth, seasonal variation, type of soil, nature of fertilisers used, etc. [Kelley and Thompson, 1910].

A preliminary analysis of the protein and mineral contents of two varieties of rice grown under different manurial treatments at the Agricultural Research Stations in Coimbatore and Pattambi respectively was carried out.

The results together with the details of treatments are given in Tables VI and VII.

TABLE VI

Seed-bed manurial experiments with Co 10 conducted at Coimbatore (1935)

Analysis of grain

Details of manuring			Percentages		
	Seed-bed	Transplanted field	Protein	Ash	P_2O_5
I (*i*)	No manure . .	No manure . .	8·20	1·72	0·674
I (*ii*)	No manure . .	Manured (2 cwts. super *plus* 1 cwt. amm. sulphate *plus* 4,000 lbs. green leaf).	8·76	1·64	0·699
II (*i*)	Normal manuring (5,000 lbs. green leaf per acre).	No manure . .	8·17	1·56	0·699
II (*ii*)	Do. . . .	Manured . . .	8·22	1·84	0·742
III (*i*)	Heavy manuring (2,000 lbs. green leaf *plus* 1 cwt. amm. sulphate *plus* 1 cwt. super per acre).	No manure . .	7·94	1·20	0·707
III (*ii*)	Do. . .	Manured . . .	8·56	1·60	0·735

TABLE VII

Manurial experiments with GEB 24 conducted at Pattambi (1935)

Analysis of grain

Manurial treatment	Percentages		
	Protein	Ash	P_2O_5
(*i*) Leaf at 2,000 lbs. per acre	10·28	1·32	0·564
(*ii*) Same as (*i*) + super 112 lbs. per acre . . .	10·03	1·40	0·580
(*iii*) Same as (*ii*) + amm. sulph. 30 lbs. at planting time .	10·42	1·08	0·577
(*iv*) Same as (*ii*) + do. 1 month later	10·45	0·98	0·577
(*v*) Same as (*ii*) + do. 2 months later	12·27	0·88	0·582
(*vi*) Same as (*ii*) + 15 lbs. at planting time + 15 lbs. one month later	10·21	1·18	0·608
(*vii*) Same as (*ii*) + 15 lbs. at planting time + 15 lbs. two months later	10·88	1·68	0·600
(*viii*) Same as (*ii*) + 10 lbs. at planting time + 10 lbs. one month later + 10 lbs. two months later.	10·86	1·58	0·544

The results (Tables VI and VII) indicate the possibilities of enriching the composition of the kernels by suitable fertiliser application. In particular, it would appear that application of fertilisers, in instalments during the life of the crop and up to the flowering period, is definitely favourable, the protein content being increased to the extent of 20 per cent in one case. Further work relating to the influence of manuring on the yield and composition of the rice grain is in progress. The influence of soil and climatic factors on the chemical composition and nutritive value of rice is also being studied by growing the same variety of rice under identical manurial treatments at different centres. The effect of application of artificial fertilisers and organic manures on the quality of the grain will also be investigated.

SUMMARY

1. Chemical analyses of different varieties of rice grown in the Agricultural Research Stations of the Madras Presidency were made and the changes in composition as a result of (*a*) polishing, (*b*) parboiling, and (*c*) parboiling and polishing studied.

2. Parboiled rice, unpolished, or polished till free from bran layers, is not very different in composition from the corresponding specimen of raw rice.

3. Among commercial samples, parboiled (milled) rice is slightly richer in proteins and minerals than raw (milled) rice, due probably to a lesser degree of polishing in the former case.

4. Coloured and coarse-grained varieties of rice usually contain greater percentages of protein and minerals—particularly phosphorus—than fine-grained varieties. Such rices also require a greater degree of polishing than the others before obtaining a white (polished) grain.

5. Polishing results in a loss of about 30 per cent in fats, 25 per cent in proteins, and 50 per cent in ash constituents of the rice grain.

6. Indications have been obtained to show that the composition of rice varieties (proteins and minerals) can to some extent be enriched by suitable fertiliser applications.

The authors' thanks are due to Professor V. Subrahmanyan, D.Sc., F.I.C., F.N.I., for his kind interest and to the Imperial Council of Agricultural Research for a personal grant to one of us (A. S.).

REFERENCES

Acton, H. W.; Ghosh, S. and Dutt, A. (1933). *Ind. J. Med. Res.* **21**, 103

A. O. A. C. (1935). Methods of Analysis

Aron and Hocson (1911). *Biochem. Zeit.* **32**, 189 (also *J. Chem. Soc.* 1911, *abs.* **2**, 625)

Balland (1895) *Compt. rend.* **121**, 561 (also *J. Chem. Soc.* 1896, **2**, 212)

Basu, K. P. and Sarkar, S. N. (1935). *Ind. J. Med. Res.* **22**, 745

Borassio, L. (1930). *Chem. Abstr.* **24**, 1677, 4557

Brown and Chiquelin (1904). *Bull. Agric. Expt. Stn. (Louisiana), No.* **77**

Church (1886). 'Food Grains of India,' p. 73

Fraps, G. S. (1916). *Texas Agric. Expt. Stn. Bull.* **191**

Hooper, D. (1908-09). *Agric. Ledger No.* **5**

————---(1912). *Agric. Ledger No.* **7**

Joachim, A. W. R. and Kandiah, S. (1928). *Trop. Agric. (Ceylon)* **70**, 195

Kelley, W. P. and Thompson, A. R. (1910). *Hawaii Expt. Stn. Bull.* **21**

Kellner (1889). *Bull. Imp. Coll. Agric. Tokyo* **1**, No. 5

Kellner and Nagaoka (1892). *Bull. Imp. Coll. Agric. Tokyo* **1**, No. 12

Kennedy (1924). *J. Agric. Res.* **27**, 219

Krauss ; Kelley, W. P. and Thompson, A. R. (1907). *Hawaii Agric. Expt. Stn. Repts.*

Leather, J. W. (1903). *Agric. Ledger No.* **7**

McCarrison, R. and Norris, R. V. (1924). *Ind. Med. Res. Mem. No.* **2**

Ramiah, K. (1936). *Curr. Sci.* **5**, 215

Ross (1889). *Bull. Agric. Expt. Stn. (Louisiana) No.* **24**

Sen, J. N. (1916). *Imp. Agric. Res. Inst. (Pusa) Bull. No.* **62**

Sreenivasan, A. and Das Gupta, P. (1936). *Curr. Sci.* **5**, 75

Sreenivasan, A. and Subrahmanyan, V. (1935). *Curr. Sci.* **4**, 378

Subrahmanyan, V. ; Sreenivasan, A. and Das Gupta, P. (1938). *Ind. J. Agric. Sci.* **8**, 459.

Takahashi, T. and Sato, H. (1913). *J. Coll. Agric. Tokyo* **1**, No. 2

Thompson, A. R. (1915). *J. Agric. Res.* **3**, 425

Warth, F. J. and Darabsett, D. B. (1913). *Burma Dept. Agric. Bull.* **10**

Wiley (1895). *U. S. Dept. Agric. Bur. Chem. Bull.* **45**

——(1898). *U. S. Dept. Agric. Bur. Chem. Bull.* **13**

Wise, F. B. and Broomell, A. W. (1916). *U. S. Dept. Agric. Bull.* **191**

ESTIMATION OF MANGANESE IN PLANTS

BY

A. V. VARADARAJA IYENGAR, B.A., D.Sc., A.I.C., A.I.I.Sc.

Department of Biochemistry, Indian Institute of Science, Bangalore

(Received for publication on 9th May 1938)

Determination of manganese in plants and plant parts has been studied by a number of investigators. Many workers have recommended the micro method while others have adopted the macro one. Neither the gravimetric method (macro-chemical) detailed in the Official Methods [1925] nor the volumetric one selected in a later edition of the same [Official Methods, 1930] has been widely employed. It may be observed that in biological, physiological and biochemical investigations, the amount of research material for the different analyses is always limited. Hence the micro method has found extensive application with elaborate technique developed for the same. Some of these methods have also been critically examined.

The principle of estimating manganese is based on the fact that a solution of manganous salt is oxidised to permanganic acid in a strongly acid medium by per-salts such as persulphates, periodates and by peroxides of metals like lead, bismuth, etc. The permanganic acid so formed develops a fine colour which is easily estimated in a colorimeter by comparison with a permanganate solution with known manganese content. These methods have been advocated by different groups of workers. We owe a great deal to Yoe [1930] for exhaustive literature on the subject, to Willard and Greathouse [1917] for early references and to Harry [1931] for a review on the subject of estimating manganese. Rost and Gortner [1914] favoured exclusively the bismuthate method rejecting the persulphate one on the ground that the latter did not develop the true permanganate colour. The persulphate method is, inspite of this fact, very widely used. The chief objection to this method is traceable to the fact that the reaction is quite erratic even though it is catalysed by silver nitrate. On the other hand, bismuthate introduces errors traceable to the presence of small quantities of chlorides in the different preparations. This defect has since been overcome through a modified procedure developed by Subrahmanyan and coworkers [1935]. The oxidation of manganese by periodate developed by Willard and Greathouse is still the method for final reference. Recently, Davidson and Capen [1931] compared the three methods. They eliminated the bismuthate procedure as being erroneous but obtained closely agreeing results in the other two methods. It is pertinent to remark here that this agreement holds good only in the case of three while with the rest of the samples, the range in difference in values is anywhere between — 8 to + 20 per cent of the periodate value. Moreover with pure manganese oxide the authors obtained values far higher than the theoretical ones, thereby leaving their conclusions open to verification by others.

The question was therefore re-examined at length by the author. Though the lead peroxide method was first described by Crum [1845] it has not been widely adopted in spite of certain distinct advantages which it possesses over the others. Firstly, Hoppe-Seyler [1863] brought evidence to show that the colour developed by lead peroxide with manganese was *spectroscopically* the same as that of the ordinary permanganate, a fact which has apparently been overlooked. But it eliminates at once all the controversies raised by Rost and Gortner and others and establishes its adaptability for quantitative determination of manganese under satisfactory working conditions. Secondly, it is cheaper than all the other reagents including ammonium persulphate. A large amount of this chemical will be available even in ordinary laboratories. Further it can be obtained in a pure form without increasing the cost. Its reaction is quantitative being represented by the equation :—

$$2Mn(NO_3)_2 + 6HNO_3 + 5PbO_2 = 5Pb(NO_3)_2 + 2HMnO_4 + 2H_2O$$

and takes place in a strongly acid medium. No accurate weighing is needed as with periodate. It therefore appeared possible to employ this method if only the working conditions were satisfactorily determined. A study of the influence of the determining factors in the estimation of manganese is communicated in the present paper.

EXPERIMENTAL

In the following experiments, solutions containing weighed amounts of pure manganous sulphate and potassium permanganate have been employed. The permanganate was standardised against standard sodium oxalate and ferrous ammonium sulphate, both Kahlbaum's special ('pro analysis') reagents, and the manganese content was computed from these. In the case of manganous sulphate, the amount of manganese was determined independently by the gravimetric method, using Volhard's method of titrating it against standard permanganate and by precipitating it as phosphate and reckoning as pyrophosphate after ignition [Treadwell and Hall, 1919]. The permanganate solution was reduced with oxalic acid, excess being suitably removed and made up to a convenient volume and similarly examined. The results of this comparative examination are presented below.

TABLE I

Manganese content of manganese sulphate solution (expressed as mg. Mn_3O_4)

Volume of solution in c.c.	Phosphate method	Volhard's titration method	Gravimetric method
20	6·40	6·40	6·35
30	9·55	9·63	9·42
40	12·77	12·76	12·60
50	15·90	15·97	15·80
25*	9·86	9·90	9·78

*Standard permanganate 1·33625 *N*/50.

It will be seen that the titration against permanganate gives the highest values and may be taken as correct.

Influence of acidity on the stability of permanganate colour.—In the course of some preliminary studies it was found that the permanganate tint diminished in intensity with low concentration of the added acid. With a view to getting at the correct concentration of acid to avoid this defect, pure permanganate solutions were diluted with concentrated nitric, sulphuric and phosphoric acids respectively, and examined periodically. The results are tabulated below :—

TABLE II

Concentration of acid in relation to stability of permanganate colour
(Dilute permanganate solution 10 c. c. ; total volume 20 c.c.)

Volume of water in c.c.	Volume of acid in c.c.	Reaction of the final solution to acid			
		Phosphoric (1 : 1)	Nitric	Sulphuric (1 : 1)	Nitric and phosphoric (3 : 1)
10	0	*	*	*	*
8	2	*	†	†	*
6	4	*	†	†‡	*
5	5	*	†‡	†‡	*
4	6	*	‡†	†‡	*
2	8	*	‡†	†‡	*
0	10	*	‡†	†‡	*

* = No change in the original tint of permanganate

† = Change in the original tint to light crimson

‡ = Formation of a precipitate after a time

It is evident from the above table that phosphoric acid alone retains the original tint while in the presence of nitric and sulphuric acids, the change in the colour of the permanganate is very prominent and does not at all compare with the permanganate tint. The loss of the initial tint was found to depend on the concentration of the acid : the stronger the acid the more rapid the fading. Finally a brick colour solution was obtained with the formation of a brown precipitate. It was found that when the acid strength was about 25-30 per cent, the loss in colour was negligible only in the presence of phosphoric acid.

Comparative determinations of manganese with lead peroxide.—Manganese in the solutions referred to earlier was estimated as follows :—Ten c.c. of the solution were mixed in a conical flask with 30 c.c. of nitric acid (2 : 1) to which pure lead peroxide (Kahlbaum) was added (5 grams) for each estimation The nitric acid was previously freed from oxides of nitrogen through aeration

The solution was heated on sand bath for twenty minutes, and with the development of full colour, the flask was removed, cooled suddenly, filtered and washed with dilute phosphoric acid (1 : 1). The combined filtrates were transferred to a 50-c.c. measuring flask and the volume made up with carbon dioxide-free water.

The method appears simple, but some difficulty is experienced in filtering the solution. In view of the finely divided condition of the peroxide a second filtration of the solution is often quite necessary when filtered through filter paper. Besides, there is a distinct and definite loss in the intensity of the final colouration which is accelerated by the use of ordinary distilled water, since this generally contains some carbon dioxide. To obviate these difficulties, the solutions were filtered in the following manner through Jena filter crucibles designated '14 a G 4'. A thin layer of treated blue asbestos spread over the filtering surface, was first washed with very dilute permanganate followed by distilled water, thereby eliminating the possible absorption of permanganate by the asbestos from the test liquid. The solution was then filtered warm by decantation and the lead peroxide washed with dilute phosphoric acid. Carbon dioxide-free water was used to make up the volume. The final solution so obtained compared most favourably with that oxidised with potassium periodate in the case of manganese sulphate, and with diluted permanganate where the permanganate was first reduced and subsequently re-oxidised. A great advantage with lead peroxide method is the ease with which the unused reagent can be recovered highly pure and can be re-employed.

The colour developed by lead peroxide was compared with that formed by potassium periodate for which the directions of Willard and Greathouse [1917], were closely followed.

Influence of acid concentration.—With a view to studying the quantity of acid necessary for the oxidation of manganese, 10 c.c. of the solution were treated with excess of lead peroxide and varying amounts of nitric acid, and heated for twenty minutes on a hot sand bath in the manner described before. The standard was also similarly treated with periodate. The results are presented in Table III.

TABLE III

Manganese in 10 c.c.	0·640 mg.
Lead peroxide used	5·0 grams.
Phosphoric acid (1 : 1)	10 c.c.
Total volume	50 c.c.
Time of heating	20 minutes.

Acid (concentrated) in c.c.	5	10	15	20	25	30
Per cent manganese estimated	67·8*	74·3	87·8	99·4	99·0	99·6

*Each is a result of a dozen independent readings.

Substitution of nitric by sulphuric acid was tried with scarcely any difference, though the formation of lead sulphate caused some difficulty in filtration. It will be seen that 20 c.c. of the strong acid is sufficient when the final volume is only 50 c.c. It may be added that this minimum in the concentration of nitric acid required increases with the concentration of manganese.

Influence of time of heating.—Although in previous experiments the time of heating was arbitrarily fixed at twenty minutes, it was considered important to determine the maximum time for the development of the optimum intensity of colour. The above experiment was repeated varying the time alone and keeping the other factors constant. The data are reproduced in Table IV.

TABLE IV

Time of heating in relation to production of colour

Time of heating in minutes	6	9	12	15	18	22
Manganese recovered (in per cent)	70·6	85·8	98·0	99·5	99·6	99·1

It is sufficient to heat the solution for fifteen minutes on a hot sand bath to obtain the maximum colour. This is found to be independent of the amount of manganese contained in the solution.

Influence of the amount of peroxide added.—The quantity of lead peroxide required to oxidise one mg. of manganese is comparatively small, according to the equation expressed above. In practice, however, it is difficult to realise this condition. In fact, even with considerably higher amounts, the reaction does not appear to be complete as can be seen from Table V.

TABLE V

Effect of different quantities of the oxidising agent

Manganese in 10 c.c., 0·640 mg.; Nitric acid, 10 c.c.; Time of heating, 15 mins.; Total volume 50 c.c.

Lead peroxide in grms.	0·5	1·0	2·0	3·0	4·0	5·0
Manganese estimated as per cent	79·3	90·3	98·1	99·2	99·8	99·4

It is difficult to account for this variation but it appears that at least 2·0 grms. of the oxidising agent must be present. It is interesting to know that this excess can be easily recovered subsequently. It has been found that the amount of lead peroxide required decreases to some extent with higher concentrations of acid. Thus with 40 per cent acid, the quantity of oxidising agent necessary is 1·5 grams.

The conclusions arrived at in the previous paragraphs were verified with different amounts of manganese and were found to agree with one another very closely. Thus, the utility of this method in the colorimetric method of determining this element seems to be adequately established.

Influence of iron in the estimation of manganese.—It is well recognised that the presence of iron interferes with the tint of permanganate produced. It was therefore important to know whether the quantities normally present in plant parts would limit the applicability of this method. It has been suggested that the addition of phosphoric acid would eliminate the difference in tint due to ferric salts. It was also found that this technique enabled the matching of the colours. The same procedure was adopted for oxidising the manganese as described before. Equal amounts of iron were also added to the standard solutions. Ferric nitrate (Kahlbaum ' pro analysis ') solution was used as the source of iron, containing 0·60 per cent iron as ferric oxide, in the following trials. The data are reproduced in Table VI.

TABLE VI

Effect of iron on the determination of manganese

Volume of iron nitrate in c.c.	1·0	2·0	3·0	4·0	5·0	6·0	8·0	10·0
Per cent manganese estimated	98·8	99·3	99·2	99·5	99·1	98·9	99·2	98·7

It is evident that the addition of ferric salts does not affect the permanganate tint, provided there is sufficient phosphoric acid present in the final solution. The above experiment was repeated with reduced permanganate solution containing various proportions of this salt and compared against the diluted original one. The results were found to agree very closely with the above, thereby establishing the fact that the colour formed was not masked by the presence of iron.

Comparison between persulphate, bismuthate and lead peroxide methods.—This comparative study was carried out on pure manganese salt and reduced potassium permanganate solutions, as well as on some plant parts, with a view to testing the efficacy of the improved lead peroxide method. Further tests were carried out with pure solutions, in the presence of iron added as nitrate. In the case of plant parts, the presence of iron in them was considered sufficient for this examination. Ammonium persulphate (pure, Kahlbaum) and sodium bismuthate (' pro analysis ') reagents were employed. Details described by Yoe [1930] for these were closely followed. The results secured in this case are reproduced below (Table VII).

TABLE VII

Comparative estimation of manganese by different methods (each value represents an average of 12 readings)

Nature of the oxidising agent	Per cent manganese estimated in			
	Manganese sulphate alone	Manganese sulphate with iron nitrate	Reduced permanganate alone	Reduced permanganate with iron nitrate
Potassium periodate .	..	..	99·6	99·3
Sodium bismuthate .	92·8	93·3	95·2	94·9
Ammonium persulphate .	78·9	75·1	74·9	78·6
Potassium persulphate .	84·2	86·8	85·7	88·8
Lead peroxide .	98·6	99·1	99·3	99·1

It follows from this table that lead peroxide oxidises manganese quantitatively. The low value obtained with the bismuthate method may be due to traces of chloride detected therein. In the case of persulphates, it was noticed that the shade of colour which developed did not correspond to that of the real permanganate or to that developed by periodate or peroxide or even bismuthate. Moreover, large variations in the final values were obtained which had to be rejected in spite of following the directions closely.

With plant parts.—Cotton plants, rice straw, sandal leaf, and some grasses were examined. The specimens were dried free from moisture and powdered. Duplicates were run in each case utilising 10 grms. of the oven-dry material for each estimation. The following method was adopted for ashing plant materials. Weighed amounts of samples were treated with the minimum of concentrated sulphuric acid (A. R. tested for manganese) and stirred with a glass rod so as to char the material uniformly. When the mass was dry and hard, it was ignited over a low flame until the final product was practically free from carbon. Ashing is quicker and complete by this method, which helps to remove the chlorides also. The ash was then treated with warm dilute sulphuric acid (1 : 25), evaporated nearly to dryness and again extracted with dilute nitric acid. It was filtered, washed and made up to volume. Aliquots were used to determine manganese by the improved method against permanganate solution containing known quantities of this element. The results obtained with different plant materials are reproduced below (Table VIII).

TABLE VIII

Manganese content of plant parts (expressed as per cent Mn_3O_4*) on moisture-free material*

Plant species and part studied	Lead peroxide	Potassium periodate	Sodium bismuthate	Ammonium persulphate
Grass (whole)	0·280	0·284	0·268	0·254
Grass (whole)	0·103	0·106	0·009	0·008
Wheat (*bhusa*)	0·016	0·016	0·015	0·013
Oat (hay)	0·0084	0·0084	0·0074	0·0064
Sandal (leaf)—				
healthy	0·0258	0·0264	0·0248	0·0236
spiked	0·0384	0·0388	0·0371	0·0350
Cotton (seed)—				
American	0·0021	0·0021	0·0020	0·0018
Indian	0·0015	0·0015	0·0014	0·0012
Cotton (buds)—				
American	0·0170	0·0175	0·0170	0·0160
Indian	0·0138	0·0140	0·0120	0·0104
Cotton (leaves)—				
American	0·0198	0·0204	0·0178	0·0154
Indian	0·0142	0·0150	0·0130	0·0116

DISCUSSION

The application of lead peroxide as an oxidising agent for the conversion of manganese to permanganate has received attention from early investigators, but it has somehow not been widely adopted. As in the case of sodium bismuthate, the excess reagent has to be removed by filtration or decantation and thus suffers a great disadvantage as compared with the standard periodate method. The adoption of Jena filters has eliminated this inconvenience in addition to expediting the analytical estimations.

The nature and concentration of acid were found to be important factors in manganese estimation. Sulphuric acid affects the colour of permanganate solutions (Table II). Nitric acid retains the colour for a short time but with added phosphoric acid the duration of the tint is almost permanent as with phosphoric acid alone. This fact has been made use of in the present contribution. The addition of phosphoric acid obviates errors due to the presence of iron which occurs largely in plant parts (Table VI).

In view of the fact that the retention of the tint and the rate of oxidation are quite normal with 40 per cent nitric acid in the medium (Table III), it is necessary to maintain this minimum concentration in addition to the acid required for effecting the conversion of manganese to permanganate according to the equation referred to earlier. Sulphuric acid is not so efficient as nitric acid. The time of heating was found to be in the neighbourhood of fifteen minutes and independent of the concentration of manganese (Table IV). In regard to the oxidiser itself, it may be stated that even with high acid content the addition in half-gram lots of lead peroxide as recommended by Treadwell [1919] was not helpful. It was necessary to have a minimum of 1·5 grams besides that required for oxidation purposes for completing the reaction. The lead peroxide is quite cheap and easily recovered and purified after use.

It will be seen from Table VII that on the basis of periodate method which has been reckoned and recommended as one for reference, lead peroxide oxidation of manganese gives the greatest per cent conversion. With persulphates the findings of Rost and Gortner [1914] were confirmed, the change in colour of permanganate arising from the free sulphuric acid liberated. In the case of permanganate, lead peroxide gave almost equal values with those of periodate.

Similar tests carried out on different plant parts (Table VIII) have again indicated the superiority of lead peroxide excluding the periodate method.

The application of lead peroxide in presence of nitric acid is thus a very useful technique to be employed in plant analysis for determining manganese. It may be suggested that the same can be applied to soils and to minerals with slight modifications. One serious objection against it will be that the oxidised solution cannot be preserved as is the case with periodate. But it was found that this condition could be realised if the oxidised solution were preserved without being filtered. The tint then keeps for very long intervals.

SUMMARY

1. An examination has been made of the applicability of lead peroxide for the oxidation of manganese to permanganate with a view to improving this method for adoption in routine analysis.

2. It was found that nitric acid concentration, time of heating and, to some extent, the amount of lead peroxide used, were factors which influenced the rate of oxidation of manganese.

3. An easy and rapid method has been described.

4. The stability of the tint in presence of iron salts was tested and found to be maintained through the addition of phosphoric acid.

5. The improved lead peroxide method was found to compare very favourably with the periodate technique both with pure salts and with different plant parts studied.

The author's thanks are due to Prof. V. Subrahmanyan, D.Sc., F.I.C., for his interest in this work.

REFERENCES

Crum, W. (1845). *Ann.* **55,** 219

Davidson, J. and Capen, R. G. (1931). *J. Assoc. Agric. Chem.* **14,** 547

Harry, R. G. (1931). *J. Soc. Chem. Ind.* **50,** 434T

Hoppe-Seyler, J. (1863). *J. Prakt. Chem.* **90,** 303

Official Methods (A. O. A. C.). 1925 & 1930 editions

Rost, C. O. and Gortner, R. A. (1914). *Ind. Eng. Chem.* **6,** 522

Subrahmanyan, V. *et al.*, (1935). *Proc. Ind. Acad. Sci.* **2B,** 111

Treadwell, F. P. and Hall, W. T. (1919). "Analytical Chemistry", Vol. II. Quantitative Analysis : John Wiley & Sons, New York

Willard, H. H. and Greathouse, L. H. (1917). *J. Amer. Chem. Soc.* **39,** 2366

Yoe, J. H. (1930). "Photochemical Analysis", Vol. I. Colorimetry : John Wiley & Sons, New York

A METHOD OF DISPERSION OF SOILS FOR MECHANICAL ANALYSIS

BY

JOGENDRA NATH CHAKRABORTY

Agricultural Chemistry Section, Department of Chemistry, Dacca University

(Received for publication on 11th April 1938)

OBJECTIONS to treatment of soils with hydrogen peroxide for mechanical analysis, which is necessary according to the International-A method have been mentioned and potassium permanganate has been found by the author to be a suitable substitute for this reagent [Chakraborty, 1936].

Davies [1933] found that organic matter in certain New Zealand soils could not be easily decomposed by hydrogen peroxide and that addition of ammonia solution or a trace of manganese dioxide helped the oxidation of organic matter by hydrogen peroxide.

In a discussion on " Mechanical Analysis and Field Texture ", Olmstead [1935] expressed himself against the removal of lime stone from the soil sample by drastic acid treatment when dispersion can be effected without the use of hydrochloric acid. Any other treatment which is less drastic and which will disperse as much colloids from soils as by treatment with 0·2 *N* hydrochloric acid would be preferable to the latter.

In a previous publication by the author [Chakraborty, 1935] a method of dispersion of soils for mechanical analysis has been outlined. In this method organic matter in soil is removed by heating the soil with a fairly dilute solution of potassium permanganate ; other cementing materials, such as calcium carbonate, present in the soil are destroyed by 0·2*N* hydrochloric acid. The precipitated hydrated manganese dioxide is removed by sodium bisulphite in presence of dilute hydrochloric acid. In the present paper changes in the above method are described which avoid treatment with 0·2*N* hydrochloric acid and also yield reproducible results for the clay and the clay+silt fractions in satisfactory agreement with those of the International-A method.

Reagents required :

1. Normal sodium hydroxide.
2. Normal potassium permanganate. Fifty c.c. are capable of oxidizing 0·09 grm. of organic carbon in an alkaline medium with liberation of 10 c.c. normal alkali.
3. Grape sugar.
4. Normal hydrochloric acid.

5. Ten per cent solution of ammonium acetate.
6. Sodium hydrosulphite ($Na_2S_2O_4$) ; a concentrated solution prepared just before use.
7. Acidified sodium acetate solution, prepared by dissolving 100 grms. of sodium acetate (crystalline) in a litre of water and made just acid to methyl orange, before use with normal hydrochloric acid.
8. Benzidine acetate ; 1 per cent in water and sufficient acetic acid for solution.

EXPERIMENTAL

(*a*) *Oxidation of organic matter.*—Ten grms. of air-dry soil are taken in a 600-c.c. Pyrex beaker, 25 c.c. permanganate and 2·5 c.c. normal sodium hydroxide are added in succession. The beaker is placed over a sand bath and rotated to help mixing of contents. As soon as permanganate colour disappears fresh additions of 25 c.c. (50 c.c. in soils containing large quantities of organic matter) of the permanganate solution are made until after the last addition the permanganate is not decolorised on heating for thirty to forty minutes.

In soils containing gypsum 15 c.c. of normal sodium hydroxide for each gram of calcium sulphate present in the soil must be added gradually during the course of the above oxidation.

(*b*) *Removal of hydrated manganese dioxide.*—After the oxidation, the beaker is taken out of the sand bath and a very small quantity of grape sugar is added to decolorise the excess of permanganate. The beaker is cooled. The alkali added to the soil and that produced during the oxidation are neutralised with normal hydrochloric acid using a blue litmus paper as an external indicator. If neutralisation with acid is not liked, the contents after process (*a*) while still hot, may be poured into a 15-cm. filter paper and washed with about 50 c.c. water. The residue in the filter paper is transferred to the beaker in which oxidation was carried out. One hundred c.c. of 10 per cent ammonium acetate is next poured into it and a strong solution of sodium hydrosulphite is added, little by little, stirring the soil after each addition, until the whole of the precipitated manganese dioxide goes into the solution. About five to seven minutes are required for this reduction. Although a complete solution of manganese dioxide is essential at this stage, addition of sodium hydrosulphite should only be just sufficient. The soil is stirred for one minute and then allowed to settle. The clear supernatant liquid is poured into a 15-cm. filter paper and the residue is transferred and washed with 50 c.c. of 5 per cent ammonium acetate solution.

(*c*) *Separation from coarse particles.*—The soil in the filter paper as well as in the beaker is transferred and gently rubbed with finger into a 70-mesh sieve placed on a beaker and washed with a jet of water until only clear water passes through.

(*d*) *Removal of exchangeable calcium and its salts.*—One hundred c.c. of 10 per cent ammonium acetate and 1 to 2 grm. of grape sugar are added to the soil and the liquid in the beaker is made up to about 300 c.c. The contents of the beaker are boiled briskly for thirty to forty minutes (40 minutes in case of soils containing large amount of organic matter or calcium carbonate). The soil is allowed to settle and the hot clear liquid is passed through a 15-cm. filter paper. (Boiling with 100 c.c. ammonium acetate and 200 c.c. water was repeated for half an hour in case of soil No. 24, Table I). If any manganese dioxide is noticed sticking to the side of the beaker while boiling, the soil in the beaker, after transference of the clear supernatant liquid is cooled and agitated with hand for three to four minutes with addition of about 0·1 to 0·2 grm. of sodium hydrosulphite. The soil is transferred to the filter and washed with 50 c.c. of 10 per cent ammonium acetate.

(*e*) *Washing free from manganese.*—The soil is further washed with 50-c.c. lots of acidified sodium acetate solution allowing the filtrate to drain off completely before a fresh addition of acetate solution is made, until a drop of the filtrate gives a very faint blue colour by benzidine acetate test. A black precipitate indicating presence of manganese is not obtained at this stage by boiling a little filtrate with bromine water and then with a little ammonia. Generally washing with 200-250 c.c. of sodium acetate has been found to be enough to make the soil free from manganese. The benzidine acetate test may be carried out as follows. When only a small quantity of the washing liquid is present in the filter, about 0·5 c.c. of the filtrate is collected in a test tube and two drops of nitric acid are added to it. One drop from the test tube is taken on a filter paper (gravimetric) and a drop of normal caustic soda is placed on it. A drop of benzidine acetate gives blue colour.

(*f*) The residue is next washed with 50 c.c. of water and transferred into a 500-c.c. bottle with 4 c.c. of normal caustic soda for 10 grm. of soil used. The bottle is shaken on an end-on-end-over shaker for six hours at the rate of forty revolutions per minute. The contents of the bottle are made up to 2 litres and subjected to pipette sampling for determination of clay and clay + silt.

(*g*) *Determination of loss on solution.*—The total filtrate from (*b*), (*d*), (*e*) and (*f*) is acidified with hydrochloric acid and made up to a definite volume; 1/10th of the volume is taken in a beaker and boiled with 5 c.c. concentrated nitric acid. If any precipitation of sulphur takes place, the liquid is filtered and the loss on solution is determined in the filtrate according to the method of Lundell and Knowles [1923]. This method has been described by Treadwell and Hall [1930] and also by the author [Chakraborty, 1935].

EXPERIMENTAL RESULTS AND DISCUSSION

TABLE I

Oven-dry clay and clay+silt in air-dry soils by different methods

Soil No.	Lab. No.	Locality	International-A method H_2O_2—HCl—NaOH			Proposed method; alkali present in the soil after treatment with alkaline permanganate is neutralised with *N* HCl			Proposed method; alkali present in the soil after treatment with alkaline permanganate is removed by filtration and a little washing		
			One per cent suspension of 20 grm. soil shaken for 24 hours with 8 c.c. *N* NaOH			0·5 per cent suspension of 10 grm. soil shaken for 6 hours with 4 c.c. *N* NaOH			0·5 per cent suspension of 10 grms. soil shaken for 6 hours with 4 c.c. *N* NaOH		
			Clay (per cent)	Clay+silt (per cent)	Loss on solution (per cent)	Clay (per cent)	Clay+silt (per cent)	Loss on solution (per cent)	Clay (per cent)	Clay+silt per cent)	Loss on solution (per cent)
1	105	Bengal; Dacca, Bikrampur	21·2	62·3	1·5	21·0	61·1	1·15	21·1	63·2	1·0
		Bengal soils sent by the Agricultural Chemist, Bengal									
2	107	Rajshahi Farm	23·1	58·2	0·8	22·4	56·0	0·66			
3	108	Berhampur Farm	19·8	47·1	0·9	20·0	46·6	0·51			
4	109	Barisal	23·1	87·2	1·4	22·0	86·2	0·84			
5	110	Jessore	17·2	38·1	0·9	18·3	38·5	0·52			
6	111	Jalpaiguri, Maynaguri Farm	9·1	44·8	1·2	9·3	43·6	0·94			

7	112	Siliguri	5·5	14·0	1·5	6·9	14·8	1·02	6·8	14·7	0·17
8	113	Midnapore	20·5	47·8	0·7	20·7	46·0	0·97			

Bengal forest soils sent by the Divisional Forest Officer, Silvicultural Division, Darjeeling, Bengal

9	137		6·6	15·6	1·6	7·0	16·1	0·84			
10	140		9·1	18·5	2·2	9·7	19·0	1·69	9·1	18·1	1·21
11	143		14·0	29·6	1·5	13·3	29·7	1·5	12·6	29·1	1·56

Soils sent by Rao Bahadur B. Viswa Nath, Imperial Agricultural Chemist

12	120	Coorg, Nulkund Estate, Soil I .	45·7	62·6	1·4	44·9	60·4	2·47	42·7	60·0	1·1
13	121	Assam, Jorhat . . .	9·0	23·8	0·7	10·4	23·5	0·6			
14	122	Madras, Guntur tobacco soil .	43·8	56·6	0·9	44·8	56·8	0·4			
15	123	Bombay, Gujarat, Sursa tobacco soil.	14·9	24·5	0·8	15·6	23·8	0·6			

Black cotton soils sent by Dr. J. K. Basu, Soil Physicist, Padegaon, Bombay. Soil Nos. 16, 19 and 20 contain 11·6, 9·6 and 14·3 per cent calcium carbonate respectively

16	114	Mahalung (Nira, Right bank canal).	56·2	67·9	1·8	56·0	67·5	1·7	59·6	69·9	1·1
17	115	Durgapur (Pravara left bank canal).	52·9	71·9	1·7	54·0	71·3	0·58			
18	116	Lohagaon (Pravara left bank canal).	45·7	59·7	1·8	46·9	59·4	0·6			
19	117	Nimbut (Nira left bank canal).	57·1	71·9	1·7	58·2	72·8	0·36			
20	118	Velapur (Godavari right bank canal).	50·3	68·6	1·6	49·4	66·8	1·05	53·7	69·1	0·63
21	119	Sonewadi (Godavari right bank canal).	49·1	64·4	1·7	50·4	63·3	0·54			

TABLE I—*contd.*

Soil No.	Lab. No.	Locality	International-A method H_2O_2—HCl—NaOH			Proposed method; alkali present in the soil after treatment with alkaline permanganate is neutralised with *N* HCl			Proposed method; alkali present in the soil after treatment with alkaline permanganate is removed by filtration and a little washing		
			One per cent suspension of 20 grm. soil shaken for 24 hours with 8 c.c. *N* NaOH			0·5 per cent suspension of 10 grm. soil shaken for 6 hours with 4 c.c. *N* NaOH			0·5 per cent suspension of 10 grms. soil shaken for 6 hours with 4 c.c. *N* NaOH		
			Clay (per cent)	Clay + silt (per cent)	Loss on solution (per cent)	Clay (per cent)	Clay + silt (per cent)	Loss on solution (per cent)	Clay (per cent)	Clay + silt per cent)	Loss on solution (per cent)
Soils rich in organic matter ; percentage loss on ignition of soil Nos. 22, 23, 24 and 25 are 25·2, 22·7, 56·0 (organic matter 41·7 per cent) and 34·5 (organic matter 23·6 per cent) respectively											
22	30A	Madras	48·4	59·0	2·2	49·7	59·6	2·58	48·6	60·1	1·84
23	88	Assam	31·3	61·9	3·7	31·9	66·0	2·48	30·9	67·3	1·46
24	06	Assam peaty Bheel soil sent by Derby Tea Co.	15·2*	35·2*	3·2	17·9*	39·0*	1·69	17·4*	37·2*	1·4
25	02	Assam peaty soil sent by Sephinjuri Bheel Tea Co.	29·1*	54·5*	2·8	32·6*	58·0*	0·49			
Soils containing gypsum and calcium carbonate. Soil Nos. 26, 27, and 28 contain 8·6, 4·1 and 13·5 per cent $CaCO_3$ and 6·8, 1·6 and 2·0 per cent $CaSO_4$ respectively. Sent by Govt. Agril. Chemist, Coimbatore											
26	158	Koilpatti, 2-8 ft. . . .	49·4	57·8		50·6	58·3	1·0	53·5	60·4	0·41
27	159	Guntur, 6-9 ft. . . .	57·5	71·5		59·9	73·2	0·39	61·5	75·6	0·21
28	160	Bellary, 2-6 ft. . . .	50·1	63·5		52·0	65·3	0·4	53·8	66·0	0·18

*Ignited.

EXPERIMENTAL RESULTS AND DISCUSSION

From Table I it will appear that different types of soils either containing large quantities of organic matter, calcium carbonate or calcium sulphate, yield, by the proposed method, figures for clay and clay+silt comparable with those obtained by the International-A method. The percentage loss on solution is very low by the proposed method in which the alkali present in the soil after removal of organic matter has been filtered off. Percentage clay in soils Nos. 16, 20, 26, 27 and 28 by this method appear to be a little higher than that by the International method. It may be pointed out that these soils contain fairly large amounts of calcium carbonate.

Treatment of soils containing calcium carbonate

It may be argued that soils containing calcium carbonate should not be subjected to this method as calcium carbonate may go into solution by the action of ammonium acetate. Such soils may, however, be given a slightly different treatment.

After oxidation with alkaline permanganate the soil is filtered and washed with about 100 c.c. of water to make it almost free from alkali. The soil is transferred to the original beaker and 100 c.c. of 10 per cent ammonium chloride is added to the soil. A concentrated solution of sodium hydrosulphite is added drop by drop until all of the manganese dioxide dissolves. The soil is passed through a 70-mesh sieve with gentle rubbing, filtered and washed with 10 per cent sodium acetate solution (rendered very slightly acid to methyl red with normal hydrochloric acid. Calcium carbonate is not soluble in this reagent.) until the last few drops of the filtrate give a very faint colouration by benzidine acetate test. The soil is washed with 50 c.c. of water and shaken for six hours with either sodium oxalate, sodium citrate or any other suitable dispersing agent. In the present instance the soils have been shaken for six hours with 10 c.c. of 0·5 N sodium oxalate in 300 c.c. of water for final dispersion. The results are given in Table II.

TABLE II

Clay and clay+silt in air-dry soils by different methods

Soil No.	Lab. No.	$CaCO_3$ per cent	International-A method H_2O_2—HCl—NaOH			Proposed method for soils containing calcium carbonate		
			One per cent suspension of 20 grms. soil shaken for 24 hrs. with 8 c.c. N NaOH			Ten grms. soil in 300 c.c. water shaken for 6 hrs. with 10 c.c. $N/2$ sodium oxalate and made up to 2 litres.		
			Clay (per cent)	Clay+silt (per cent)	Loss on solution (per cent)	Clay (per cent)	Clay+silt (per cent)	Loss on solution (per cent)
16	114	11·6	56·2	67·9	1·8	55·45	76·95	0·2
19	117	9·6	57·1	71·9	1·6	60·65	76·95	0·15
20	118	14·3	50·3	68·6	1·6	44·85	76·15	0·17

From the foregoing table it appears that the percentage of clay in soil No. 20 by the proposed method for mechanical analysis of soils containing calcium carbonate is less than that by the International method ; while in case of soil Nos. 16 and 19 the figures for clay agree very fairly. It is not intended to discuss this difference further as the object of the author is to show that alkaline permanganate can be used with satisfactory results for oxidation of organic matter in these soils, without any subsequent operation which is likely to bring about a loss of soil material.

For analysis of soils, containing calcium carbonate, however, the author is inclined to recommend the permanganate method as adopted in Table I, either neutralising with an acid or removing by filtration the alkali present in the soil after oxidation treatment.

Since sodium hydrosulphite dissolves precipitated manganese dioxide more efficiently in ammonium acetate solution than in presence of ammonium chloride, on account of the slight acidity of the former, where large amount of hydrated manganese dioxide is precipitated the former should be used.

SHORT DESCRIPTION OF THE PROPOSED METHOD

Ten grms. of air-dry soil are taken in a 600-c.c. Pyrex beaker to which 25 c.c. of potassium permanganate and 2·5 c.c. of normal caustic soda are added. The soil is heated on a sand bath and stirred. As soon as permanganate colour disappears more permanganate is added in 25-c.c. lots until the last 25 c.c. added is not decolourised on heating for about half an hour.

The permanganate is decolourised with a little grape sugar. The soil is cooled and neutralised with normal hydrochloric acid. If neutralisation with acid is not desired, the soil, after oxidation of organic matter, is filtered and washed with about 50 c.c. of water. The soil is then mixed with 100 c.c. of 10 per cent ammonium acetate solution and sodium hydrosulphite is slowly added until all manganese dioxide dissolves. It is filtered and washed with 50 c.c. of 5 per cent ammonium acetate.

The soil is transferred into a 70-mesh sieve, gently rubbed with finger and washed with a jet of water until only clear water passes through.

One hundred c.c. of 10 per cent ammonium acetate is poured into the soil and 1-2 grm. of grape sugar is added. The mixture which is about 300 c.c. in volume is boiled for thirty to forty minutes. The soil is allowed to settle and the clear supernatant liquid is filtered off. In case manganese dioxide is observed sticking to the sides of the beaker while boiling, the sediment is cooled and treated with 0·1 to 0·2 grm. hydrosulphite. It is then transferred to the filter paper and washed with 50 c.c. of 10 per cent ammonium acetate.

The soil is further washed with 50-c.c. lots of acidified sodium acetate solution until the last drops of washing liquid give very faint blue colouration by benzidine acetate test.

A washing with 50 c.c. of water is given to the soil which is subsequently shaken for six hours with 4 c.c. of normal caustic soda made up to 2 litres and subjected to pipette sampling.

SUMMARY

A method of dispersion of soils for mechanical analysis has been described. This method includes treatment of the soil with alkaline permanganate for oxidation of organic matter but is free from treatment with hydrochloric acid and may be adopted by those who do not advocate the treatment of soils with acids in course of mechanical analysis.

Results for clay and clay + silt by the above method of dispersion are quite comparable with the results by the International-A method.

The loss on solution by this method is considerably less than that by the International-A method and therefore its determination may ordinarily be omitted when the proposed method is followed.

A slightly different treatment to soils containing calcium carbonate has been suggested for mechanical analysis.

ACKNOWLEDGMENTS

The author takes this opportunity to acknowledge his indebtedness to Prof. J. C. Ghosh, D.Sc., Head of the Department of Chemistry, Dacca University for his interest and encouragement during the progress of the work and to the Imperial Council of Agricultural Research, for financial help towards the purchase of necessary apparatus.

REFERENCES

Chakraborty, J. N. (1935). *Ind. J. Agric. Sci.* **5**, 41

——————(1936). *Soil Sci.* **42**, 261

Davies, E. B. (1935). *N. Zealand J. Sci. Tech.* **14**, 228

Lundell, G. E. F. and Knowles, H. B. (1923). *J. Amer. Chem. Soc.* **45**, 676

Olmstead, L. B. (1935). *Trans. Third Internat. Cong. Soil. Sci.* **3**, 189

Treadwell, F. P. and Hall, W. T. (1930). "Analytical Chemistry" (7th Edition) **2**, 156 : John Wiley and Sons, Inc., N. Y.

THE AMMONIACAL, NITRATE AND TOTAL NITROGEN CONTENTS OF RICE SOILS

BY

N. S. BAMJI

Botany Department, Royal Institute of Science, Bombay

(Received for publication on 12th May 1938)

INTRODUCTION

It is well established that ammonium salts are of greater value than nitrates to the rice plant. A complete survey of the literature bearing on this subject has already been made in previous contributions by Dastur and Malkani [1933], Dastur and Pirzada [1933] and Dastur and Kalyani [1934] on the intake of nitrogen by the rice plant, and it is, therefore, not repeated here. In view of this greater value of ammonia than nitrates to the rice plant and of the findings of Dastur and Malkani [1933] that the absorption of the ammonium ions decreases and that of the nitrate ions progressively increases as the plant ages, it would be interesting to determine the ammoniacal and nitrogen contents of the rice soils during the growing season of the rice plant. Such periodic changes in different forms of nitrogen in such soils have not been studied before in the Bombay Presidency. It is also of interest to study the relations that exist between ammoniacal nitrogen and nitrate nitrogen and of these two forms to the total organic nitrogen in such soils.

The ammonium contents of soils have been determined and found to vary from place to place depending on the nature of the soil and other factors. The ammonium content of unmanured soil was found by Russell [1910] to vary from 0·5 to 1·6 p. p. m. while in the manured soil it was found to vary from 4 to 7 p. p. m. The maximum amount of ammonia found by Mathews [1920] was 8 p. p. m. of ammonia in seven different soils. In acid soils more ammonia was found by Ellis and Morrison [1916] than in neutral soils varying from 79 parts to 296 p. p. m. Jodidi [1909, 1911, 1912] has reported as high a figure as 440 parts per million in peats. Kelley [1915] found 2 to 42 p. p. m. of ammonia in uncultivated soils while 4·2 to 33·6 p. p. m. in cultivated soils.

Work is also done on the production of different forms of nitrogen in water-logged soils. Subrahmanyan [1927] found an increase in the ammonia content in water-logged soils and he showed that increase in ammonia was neither caused by the reduction of nitrates nor by the oxidation of proteins. The increase in ammonia was also not accompanied by an increase in the bacterial numbers. He has shown that this increase was caused by some enzymic activity probably by a deaminase. Similar increase in the ammonia content in heavy and water-logged soils containing ammonium sulphate was found by Mukerji and Vishnoi [1936].

INVESTIGATION

It was undertaken to determine both the ammoniacal, nitrate and total nitrogen in small rice plots of the garden of the Institute, where rice was grown for different investigations, and also in a rice field.

The experiments in the plots of the garden of the Royal Institute of Science were performed in the rice season of 1932. The size of each plot was 100 sq. feet. Kolumba variety No. 42 was obtained from the Rice Research Station at Karjat where the seeds had been broadcast on 11th June, 1932. The seedlings were transplanted in the plots on the 16th July and the treatments were given on the 5th August.

The plots were so arranged that water from one plot would not pass directly to the adjoining plots. There were two plots receiving each treatment. Nitrogen was added at the rate of 200 lbs. per acre.

The rice field selected for the purpose was situated at Goregaon, twenty miles from the Institute. It was a field which was under rice for the last several years. It was near a railway station and had the advantage of a tank nearby for irrigation in case necessity arose from the lack of rain. The experiments were arranged on randomised basis in order to minimise, as far as possible, the errors arising out of the natural heterogeneity of the soil and due to ununiform farmyard manuring in previous years. The size of the field was one-third of an acre and it was divided into sixteen equal-sized plots. The treatments were ammonium sulphate, sodium nitrate, the mixture* of the two salts on equal nitrogen basis and the control. Nitrogen added in each case was 200 lbs. per acre. The plots were manured on the 24th August, 1933.

METHODS

The samples of soil were collected from four different spots in each plot and mixed together. This was mixed with a similar sample from the plots receiving the same treatment. So samples were collected from eight or sixteen places from plots under the same treatment in the garden soil and the field respectively. The soil for analysis is taken from a depth of 9 inches from the surface.

---

* 480 lbs. of sulphate of ammonia and 625 lbs. of sodium nitrate per acre.

After the soil samples were collected, big stones were removed by hand and the samples were dried at 55°C. in a gas-air oven fitted with a thermo-regulator. After drying the soil which took about twenty-six to twenty-eight hours, the stones were removed and weighed, the remains of roots and other remains were discarded and the rest of the soil weighed and powdered. The powdered soil was passed through a sixty-mesh sieve.

Total nitrogen was determined by Kjeldahl's method as modified by Gunning. The nitrate and ammoniacal nitrogen were determined by phenol-disulphonic and the magnesia method (C. Oslens) respectively. The results of total nitrogen in the soils of the garden plots are given in Table I. Each value is a mean of three determinations.

The total nitrogen in the control plots varies from 230 to 298 mg. on different dates. The soil samples thus show variation in their nitrogen contents to that extent. This variation may be due to soil heterogeneity.

In the treated plots, the nitrogen content of the soil varies similarly—it fluctuates from 209 to 289 mg. There is no increase in the total nitrogen noticed after manuring on 5th of August.

Thus the total nitrogen of the soils in the garden plots varies from 2100 to 2980 parts per million parts of the soil. On an average one cubic foot of dry soil weighs 86 lbs. Thus there is from 7867 to 10489 lbs. of total nitrogen per acre foot of rice soil in the garden plots. It is, therefore, natural that the addition of fertilizers at the rate of 200 lbs. per acre would give no indication of an increase in total nitrogen in the soils thus treated. The differences in the soil from place to place are greater than the differences caused by these applications.

The mean value of the ammoniacal, nitrate and total nitrogen of the soils of the eight garden plots and of sixteen plots in the rice field at different dates are given in Tables I and II.

TABLE I

Nitrogen contents in mg. per 100 grams of soil from garden plots

Month	July 1932		August 1932				September 1932					October 1932		
Date of sampling	22	29	5	12	19	26	2	9	16	23	30	7	14	21
(A) Total nitrogen														
Ammonium sulphate	269·4	254·0	269·0	248·5	270·9	258·4	249·5	292·5	266·8	265·9	243·5	241·6	233·9	243·2
Mixture	209·3	234·9	271·8	226·3	255·6	263·9	243·1	261·5	254·7	247·2	236·1	224·0	249·6	256·6
Sodium nitrate	246·7	289·4	274·2	257·9	263·2	241·8	223·7	259·3	262·2	257·9	240·0	215·2	236·1	236·8
Control	230·9	275·3	268·7	291·4	259·5	239·0	277·8	293·6	298·1	291·5	287·9	251·8	270·2	269·8
(B) Ammoniacal nitrogen														
Ammonium sulphate	5·77	7·60	6·32	7·60	7·58	6·09	10·02	13·18	10·95	6·75	5·55	5·94	9·85	6·64
Mixture	6·78	3·64	6·03	6·09	5·05	6·22	7·04	9·15	12·32	7·85	6·71	5·68	4·35	4·99
Sodium nitrate	7·40	7·86	8·18	8·05	6·22	7·01	7·66	6·62	7·36	7·40	4·88	5·11	6·27	5·55
Control	9·04	6·62	7·94	7·30	5·31	6·96	7·35	10·15	6·58	6·32	8·39	7·18	9·47	7·09
(C) Nitrate nitrogen														
Ammonium sulphate	1·00	1·14	1·02	1·89	Negligible	4·53	0·56	3·09	3·21	3·20	3·01	0·41	1·16	2·67
Mixture	1·50	1·09	1·46	3·30	0·62	Negligible	Negligible	1·26	4·88	2·26	2·70	Negligible	0·89	1·37
Sodium nitrate	4·56	1·06	0·42	1·50	2·92	4·09	0·42	2·13	2·22	2·31	1·86	,,	1·36	1·19
Control	1·06	4·01	0·91	1·73	5·19	1·30	1·08	1·05	2·54	1·77	1·97	,,	1·31	1·40

TABLE II

Nitrogen contents in mg. per 100 grams of soil from field plots

Month	July 1933		August 1933				September 1933					October 1933		
Date of sampling	22	29	5	12	19	26	2	9	16	23	30	7	12	21
							(A) Total nitrogen							
Ammonium sulphate	160·65	172·58	125·39	144·49	141·37	161·93	145·77	136·78	145·04	145·26	123·45	156·45	144·36	
Mixture	132·19	145·59	110·16	142·29	121·35	119·34	146·42	146·88	124·84	128·24	128·62	146·37	133·6	
Sodium nitrate	141·92	119·84	121·17	110·16	122·82	124·41	128·52	129·43	134·02	129·19	129·19	170·55	178·25	
Control	135·85	182·68	117·50	141·37	121·17	125·21	125·01	145·04	128·7	143·55	124·41	160·30	150·72	
							(B) Ammoniacal nitrogen							
Ammonium sulphate	5·63	4·40	2·33	2·45	4·53	4·17	4·22	4·85	4·73	3·11	3·59	4·74	5·14	
Mixture	4·86	4·79	2·72	4·22	4·01	3·97	3·71	4·86	5·24	4·52	3·41	4·64	4·42	
Sodium nitrate	5·27	3·10	2·98	2·72	2·98	3·81	4·73	4·66	4·48	3·93	2·88	4·09	3·01	
Control	5·63	5·95	3·18	3·16	3·45	4·48	3·97	5·30	5·25	5·77	4·32	3·66	3·93	
							(C) Nitrate nitrogen							
Ammonium sulphate	0·47	0·40	0·36	0·39	0·39	0·40	0·57	0·48	0·37	0·34	0·39	0·32	0·49	
Mixture	0·24	0·24	0·29	0·27	0·27	0·37	0·78	0·41	0·28	0·33	0·24	0·34	0·31	
Sodium nitrate	0·27	0·38	0·36	0·36	0·36	0·32	0·51	0·60	0·34	0·27	0·35	0·41	0·28	
Control	0·26	0·28	0·42	0·37	0·36	0·34	0·69	0·53	0·29	0·38	0·35	0·25	0·29	

The variations in the total, ammoniacal and nitrate nitrogen in the garden soils and the rice fields are given in Table III.

TABLE III

——	Garden plots	Rice field
	p. p. m.	p. p. m.
Total N	2100—2980	1000—1820
Ammoniacal N	50—120	17—59
Nitrate N	1—45	2—7

The results given in Table II indicate that nitrate nitrogen of the rice soils in fields practically remains constant throughout the rice season from July to October. If there are fluctuations from day to day and week to week, they are too small to be detected on account of the natural differences existing in the soil from place to place. If the applications of nitrate nitrogen do not give any indication of such additions, it is very unlikely that small fluctuations occurring in nature in the nitrate nitrogen content of the soils will be brought out by chemical analysis.

Similarly the ammoniacal nitrogen contents of the rice soils in the field remain fairly uniform during the rice season and no noticeable fluctuations are observed.

DISCUSSION

It would be interesting to compare if any relationship exists between the different forms of nitrogen in the soils. These relationships can best be studied by finding out the ratios between organic and ammoniacal nitrogen, between organic and nitrate nitrogen and between ammoniacal and nitrate nitrogen. The ratios when calculated showed that those between organic and ammoniacal nitrogen were more or less constant and indicate some connection between the two forms of nitrogen. Such relationship between organic and ammoniacal nitrogen was expected as the amount of ammoniacal nitrogen produced would depend upon the amount of organic nitrogen present in the soil, other conditions for the process of ammonification being uniform. Such close relationship between organic and ammoniacal nitrogen is found both in the garden plots and in the fields. The results of the ratios between ammoniacal and nitrate nitrogen show similar relationship except for some aberrant results on certain dates. It is very likely that the nitrification process depends upon the quantity of ammonia present in the soil, other conditions being equal.

The results of the ratios between organic and nitrate nitrogen showed no relationships as the values of the ratios fluctuate very widely both in the garden plots and in the fields.

The garden soils are richer in nitrogen than the soils in the field as the results of analysis show. If the results are calculated according to the mean of the four determinations irrespective of the treatments, the garden soils contain per acre-foot 8,729 to 10,377 lbs. of total nitrogen, 8,509 to 9,927 lbs. of organic nitrogen, 224 to 365 lbs. of ammoniacal nitrogen and 4 to 121 lbs. of nitrate nitrogen. In the field condition the rice soils contain per acre-foot 4,597 to 5,934 lbs. of total nitrogen, 4,323 to 5,762 lbs. of organic nitrogen, 72 to 200 lbs. of ammoniacal nitrogen, and 8 to 119 lbs. of nitrate nitrogen. The garden soils are known to be richer in nitrogen and in this particular case, the plots were manured with farmyard manure prior to transplantation of the rice seedlings. The quantities of different forms of nitrogen determined in the soils in the field agree very well with similar determinations made by other workers, *e.g.*, Harper [1926]. It was also noticed that the growth of the rice plants in the garden plots was more uniform and vigorous than those grown in the fields. The yields of straw and grain per acre in the garden plots are higher than in the plots in the field (unpublished data). It would be interesting to compare differences in the dry weight of the plant (grain and straw) in the two cases with the differences in the nitrogen contents of the respective soils. The results of the yields of straw and grain are available and are given below along with the total nitrogen contents of the soil :—

———	Total nitrogen	Yield of
		straw grain
	lbs. per acre-foot	lbs. per acre-foot
Garden plots	8729—10377	5680—3120
Field plots	4597—5934	2681—1551

The yields of straw and grain are nearly double in the garden plots and the total nitrogen in the garden plots is also nearly double the quantity found in the field plots.

In the rice soils the ammoniacal nitrogen is found to be higher than the nitrate nitrogen at all stages of the growth of the rice plant. The same relationship holds good in the garden soils where rice is grown for the last six years. The higher ammoniacal nitrogen content may be due to lack of nitrification owing to the water-logged condition of the soil, while the ammonification process may be going on normally in the soil under same conditions of moisture and temperature. It is also possible that the nitrates that are produced may be continually washed down into the deeper layers of the soil than the one-foot depth from which the soil samples in this investigation are collected while the ammonium ions remain absorbed on the surface of the soil particles. Arrhenius [1920] in studying the ammoniacal nitrate and total nitrogen-ion concentrations found that while the amount of total nitrogen was constant, that of ammoniacal nitrogen was at its maximum in the acid soils and of the nitrate nitrogen in the alkaline soils. The *p*H values of the garden soils from the same plots were determined by Dastur and Kalyani [1933] and they found that the soil remains acidic throughout the rice season and the acidic nature of the soil may thus explain the greater amounts of ammoniacal nitrogen than the nitrate nitrogen.

The applications of ammoniacal and nitrate nitrogen to the soils have not apparently resulted in the increase of these two forms of nitrogen in the soils as revealed by the chemical analysis. Still various workers have noticed beneficial effects on the growth of the rice plant by the application of ammoniacal nitrogen and the nitrate nitrogen at one stage or the other. It is therefore evident that the additional nitrogen is available to the rice plant. The total nitrogen contents of the plant manured with these fertilizers have also been found by the workers in the laboratory (unpublished data) to be higher than the control plants. It is possible that a part of the added nitrogen is immediately taken up by the roots, while the remaining nitrogen is either washed down or is too small to be detected in the soil on account of its great heterogeneity. The absence of any indication of the added nitrogen to the soil may also be due to the ununiform spreading of the fertilizer.

The results of nitrate, ammoniacal and total nitrogen of the soils treated with different fertilizers are statistically examined and the differences between different treatments are found of no significance. On the contrary, it is found that the mean yield of total nitrogen in the control treatment is significantly superior to the mean yield of the mixture and sodium nitrate treatments at one per cent level and to the mean yield of ammonium sulphate treatment at 5 per cent level. This cannot be true as the nitrogen was added to the plots in the latter cases. This indicates that the differences in the soil samples even from the same field are great and are apt to lead to wrong conclusions.

SUMMARY

The total nitrogen content of the rice soils varies from 1,000 to 1,820 parts per million ; the ammoniacal nitrogen varies from 17 to 59 parts per million, and the nitrate nitrogen varies from 2 to 7 parts per million.

Under the field conditions the addition of fertilizers have not shown any increase in the inorganic nitrogen when these soils were analysed, probably due to wider fluctuations in the inorganic nitrogen contents that occur in natural soils, and thus the small increases are obscured by them.

The ammoniacal nitrogen is higher than nitrate nitrogen. It may be due to the rice soils being acidic, for ammoniacal nitrogen is known to accumulate in the acid soils. It may also be due to the conditions in rice soils not favourable to nitrification or favourable to ammonification.

No relationship exists between nitrate nitrogen and organic nitrogen, but the ratios between ammoniacal nitrogen and organic nitrogen are more or less constant, supporting the well-established facts about the processes that lead to the production of ammonia in the soil.

REFERENCES

Arrhenius, C. (1920). ' Oecologische Studein in den Stockholmn Scharen ', 123
Dastur, R. H. and Kalyani, V. V. (1934). *Ind. J. Agric. Sci.* **4**, 803
Dastur, R. H. and Malkani, T. J. (1933). *Ind. J. Agric. Sci.* **3**, 157
Dastur, R. H. and Pirzada, A. R. (1933). *Ind. J. Agric. Sci.* **3**, 963
Ellis, J. C. B. and Morrison, C. J. T. (1916). *J. Agric. Sci.* **8**, 1
Jodidi, S. L. (1909). *Mich. Agric. Expt. Stn. Tech. Bull.* **4**, 28
———— (1911). *Iowa Agric. Expt. Stn. Res. Bull.* **1**, 1-46 ; **3**, 113-134
———— (1912). *Iowa Agric. Expt. Stn. Bull.* **9**, 327
Kelley, W. P. (1915). *Hawaii Agric. Expt. Stn. Bull.* **37**, 52
Mathews, D. J. (1920). *J. Agric. Sci.* **10**, 72
Mukerji, B. K. and Vishnoi, S. L. (1936). *Ind. J. Agric. Sci.* **6**, 17
Potter, R. S. and Snyder, R. S. (1915). *J. Ind. Eng. Chem.* **7**, 221
Russel, E. J. (1910). *J. Agric. Sci.* **3**, 233
Subrahmanyan, V. (1927). *J. Agric. Sci.* **17**, 429

LIFE-HISTORY AND MODES OF PERPETUATION OF SMUT OF SUGARCANE (*USTILAGO SCITAMINEA* SYD.)

By

JAI CHAND LUTHRA, M.Sc., D.I.C. (Lond.), I.A.S.
Professor of Botany

ABDUS SATTAR, B.Sc. (Ag.), Assoc. I.A.R.I., Ph.D., D.I.C. (Lond.)
Assistant Mycologist

and

SARDUL SINGH SANDHU, M.Sc. (Ag.)
Punjab Agricultural College and Research Institute, Lyallpur

(Received for publication on 2nd June 1938)

(With Plate LX)

CONTENTS

	Page
I. Introductory	849
II. Historical	850
III. Experimental—	
A. Material and methods	850
B. Study of the spores of the fungus—	
(*a*) Germination of spores	851
(*b*) Viability of spores	853
C. Modes of perpetuation of the disease	855
IV. Summary	860
References	861

I. Introductory

In the Punjab, sugarcane is a very important crop even though the area under it is comparatively small, being only half a million acres. Its importance lies in the fact that in certain parts of the province, it brings more profit to the cultivators than several other crops. Lately, by the introduction of improved Coimbatore varieties of sugarcane and improved methods of cultivation, the income from this crop has greatly increased.

In the Punjab, sugarcane suffers from various diseases such as smut (*Ustilago scitaminea* Syd.), red-rot (*Colletotrichum falcatum* Went.), wilt (*Cephalosporium sacchari* Butl.), stem canker (*Cytospora sacchari* Butl.), collar-rot (*Hendersonina sacchari* Butl.), top rot (*Fusarium* sp.), mosaic (a virus disease) and many others. Some of these diseases are serious and cause considerable loss to the cane-growers. But none of these diseases has been fully worked out under the Punjab conditions. The writers started work on some of the important diseases in 1934. In this paper, the life-history and modes of perpetuation of sugarcane smut (*Ustilago scitaminea* Syd.) have been described.

II. Historical

The fungus causing smut of sugarcane was first described by Rabenhorst [1870] as *Ustilago sacchari*. In India this fungus was first recorded by Sydow and Butler [1906]. Later on Sydow [1924] showed that the fungus causing smut of sugarcane in India, Java and Philippines was *Ustilago scitaminea* and that it was distinguishable from *Ustilago sacchari* Rabenh. by the size of its spores.

Ustilago scitaminea Syd. is known on sugarcane in almost all the cane-growing countries, as reported by Wakker [1895] from Java, Butler [1906] from India, Lee [1922] from Philippines, Shepherd [1924] from Mauritius, Pritchett [1924] from Louisiana, Dodds [1924] from Natal, Da Camara [1930] from Portugal, Freise [1930] from Brazil, Barat [1931] from Indo-China and Teng [1932] from China.

Wakker [1895], Krüger [1899], Delacroix and Maublanc [1911] (quoted from Dastur's paper [1920]), Ajrekar [1916], Butler [1918], Dastur [1920], Lee and Medalla [1922] and Shepherd [1924] have made some scattered observations on the methods of perpetuation of *Ustilago scitaminea* Syd., but a detailed systematic study of the disease has not been made anywhere.

III. Experimental

A. Material and methods

The smut spores, for the purpose of study, were collected from local thin sugarcane (Katha) from Lyallpur. The media and other nutrient solutions used for the study of their germination, etc., will be given in appropriate places.

Sugarcane, for the purpose of studying the modes of perpetuation, was grown in pots as well as in the field. Only such fields as had not borne any sugarcane crop for at least five years and which were away from other cane crops were selected. Generally, sugarcane was planted at the proper time, *i.e.*, from the middle of March to middle of April. But occasionally planting was also done in September in order to speed up the work. In field experiments, the Katha variety was used, and its seed canes were obtained from the Sugarcane Specialist, Risalewala, Lyallpur.

B. STUDY OF THE SPORES OF THE FUNGUS

(a) *Germination of spores*

(*i*) *Effect of different nutrient solutions on germination.*—The spores were germinated at 25-26°C., in 0·1 to 1·0 per cent solutions of sodium chloride, sodium nitrate, sodium carbonate, potassium chloride, potassium nitrate, potassium sulphate, potassium phosphate, magnesium sulphate, ammonium sulphate, $N/8$ to $N/1$ sugarcane leaf decoction, $N/64$ to $N/1$ cow-dung extract, 0·5 to 5·0 per cent glucose solution, $N/32$ to $N/1$ soil extract and distilled water.

Normal sugarcane leaf decoction was prepared by steaming for half an hour 20 grams of green leaves of Katha sugarcane in 100 c.c. of distilled water. Normal soil extract was obtained by dissolving 10 grams of soil in 100 c.c. of distilled water, allowing the solution to stand for twenty-four hours and then filtering by means of the candle pump. Normal cow-dung extract was prepared by shaking 10 grams of it in 100 c.c. of distilled water, allowing it to stand for twenty-four hours, and then filtering through ordinary filter paper.

The following results were obtained :—

1. Glucose solution (0·5 to 5·0 per cent) and sugarcane leaf decoction ($N/8$ to $N/1$) were found to be the best for the germination of spores. The germination in these solutions was so rapid and so vigorous that observations on the germination and the length of germ tubes had to be recorded after five hours of sowing, whereas in other cases these were recorded after nine hours.

2. Germination did not take place in 1·0 per cent solutions of sodium carbonate and sodium chloride and $N/2$ to $N/1$ concentrations of dung extract.

3. Germination was very low, *i.e.*, below 15·0 per cent in twenty-two hours, in 0·5 to 1·0 per cent solutions of magnesium sulphate, potassium sulphate, sodium nitrate, $N/1$ soil extract, 1·0 per cent potassium nitrate and ammonium sulphate and $N/16$ to $N/8$ concentrations of dung extract.

4. In the case of lower concentrations of the nutrients than those stated under 2 and 3 and 0·1 to 1·0 per cent potassium phosphate and potassium chloride solutions and distilled water, germination was fair to good.

5. The mode of germination of spores was similar to that described by Butler [1918].

(*ii*) *Effect of temperature on germination.*—The spores were germinated in distilled water at temperatures ranging from 5°C. to 40°C. The results are given in Table I.

TABLE I

Germination of smut spores at different temperatures

Temperature	Readings taken after (hours)	Per cent germination of spores	Average germ tube length in μ	Per cent spores bearing germ tubes		Per cent spores bearing sporidia			
				One	Two	None	One	Two	Three
5°-7°C.	12	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0
13°-15°C.	12	0	0	0	0	0	0	0	0
	24	56·6	9·2	100·0	0	96·4	0	1·8	1·9
18°C.	12	21·2	16·1	88·3	11·7	45·7	18·6	20·3	15·4
	24	78·3	40·3	77·7	22·3	13·5	8·4	57·8	20·3
24°C.	12	71·4	16·9	86·3	13·7	53·6	17·3	26·8	2·3
	24	93·4	54·8	87·8	12·2	46·3	13·8	36·9	3·0
30°C.	12	89·2	14·9	94·0	6·0	36·5	13·4	44·2	5·9
	24	94·2	53·4	94·0	6·0	26·5	20·3	46·8	6·4
36°C.	12	29·9	4·4	100·0	0	100·0	0	0	0
	24	45·8	4·4	100·0	0	100·0	0	0	0
40°C.	12	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0

The figures embodied in Table I show that the optimum temperature for the germination of smut spores is about 30°C., the maximum between 36°C. and 40°C. and the minimum between 5°C. and 13°C. The spores on germination produced either one or two germ tubes and the number of spores bearing two germ tubes was the maximum at 18°C.

The germinated spores bore sporidia at all temperatures except at 36°C. The number of sporidia per germinated spore varied from one to three.

The length of sporidia was only 5·2 μ (microns) at 13°C., while it varied from 8·06μ to 9·26μ at 18°C., 24°C. and 30°C.

(*iii*) *Effect of hydrogen-ion concentration on germination.*—The spores were germinated at 25°C. in 5·0 per cent glucose solution having a *p*H range of 1·8 to 9·8. Normal hydrochloric acid and normal sodium hydroxide were used to make different *p*H ranges and *p*H was determined by Clark's [1923] colorimetric method. The observations were recorded after nine hours and the results are given in Table II.

TABLE II

Germination of spores in 5·0 per cent glucose solution of different p*H*

*p*H	Per cent germination	Average germ tube length in μ
1·8	0	0
2·7	82·7	17·3
3·8	80·0	24·5
4·2	79·3	24·5
5·2	88·7	26·5
6·0	91·7	30·2
6·4	97·5	32·6
7·0	89·2	30·2
7·7	87·7	21·7
8·4	82·2	19·3
9·0	74·2	20·5
9·8	68·0	18·5

From the results given in the above table, it is clear that the germination of spores is very good on a wide *p*H range, *i.e.*, from *p*H 2·7 to *p*H 9·8.

The optimum *p*H for germination is 6·4 and the germination stops at *p*H 1·8 on the acid side.

(*b*) *Viability of spores*

(*i*) *Viability of spores under dry conditions at different temperatures.*—Spores of the fungus were placed in closed tubes on 31st October, 1936 in incubators at 5°C., 13°C., 20°C., 25°C., 30°C. and 35°C. Their germination was tested from time to time. The experiment remained in progress for 210 days.

The results obtained showed that even after 210 days more than 70 per cent spores remained viable at all the temperatures.

(*ii*) *Viability of spores when exposed to nature.*—Spores were placed in pots containing sterilized soil under the following conditions :—

1. On the surface of soil.
2. Buried at a depth of one inch.
3. Buried at a depth of two inches.
4. Buried at a depth of six inches.

The germination of spores was tested from time to time and the results are given in Table III.

TABLE III

Germination of spores when exposed to nature

Date of starting the experiment	Date of testing germination	Interval in days	Per cent germination			
			Spores kept on the surface of soil	Spores buried at a depth of one inch	Spores buried at a depth of two inches	Spores buried at a depth of six inches
22nd Sept. 1935	22nd Sept. 1935	0	96·3	96·3	96·3	96·3
	20th Nov. 1935	58	81·2	84·2	86·3	82·5
	31st Jan. 1936	131	78·2	81·2	78·6	78·7
	29th Apr. 1936	218	2·5	0	0	0
	24th July 1936	305	0	0	0	0

During the course of the experiment there was 0·07 inch rain in December, 1935, 0·12 inch in January, 1936, 0·58 inch in February, 1936, 1·31 inches in March, 1936, 0·69 inch in April, 1936, 4·41 inches in June, 1936 and 2·56 inches rain in July 1936.

From Table III it will be seen that under the conditions of the experiment the spores, when buried at a depth of one, two and six inches, lost viability within four to seven months. Those which were kept on the surface of soil lost viability within seven to ten months.

The above experiment was repeated in 1936-37 with similar results.

In another experiment canes smeared with smut spores were buried under soil at depths of 4 inches and 8 inches during January-February 1936. At the end of three weeks germination tests of the spores were made and it was found that all the spores had lost viability. In this interval the temperature of soil varied from 14°C. to 22°C. and there was one inch of rain. Similarly spores taken after twenty days from the surface of setts which were kept in moist soil (temperature 16°C.-31°C.) at a depth of 3 inches, failed to germinate. In addition spores were mixed in moist soil (temperature 24°C.-38°C.) and examined after three weeks. These also showed total absence of viability.

All the observations show that under moist conditions the spores lose their viability within about three weeks, but if the soil remains dry, these can remain viable for a longer period. Thus the spores which may be shed in the soil in September and October will remain viable till the planting season of sugarcane, provided there is very little or no rain during this period. This has been found to be due to the fact that under moist soil conditions and at suitable temperatures (13-36°C.) almost all the spores germinate within forty-eight hours and in the absence of the host plant the germ tubes perish.

(*iii*) *Thermal death-point of spores.*—Small capillary tubes filled with the suspension of spores of the fungus were placed in water at various temperatures ranging from 45°C. to 75°C. for five seconds. Germination trials of spores taken from these capillary tubes were made and the thermal death-point of the spores was found to be 62°C.

Some capillary tubes containing spore suspension were placed in ice. It was observed that the spores did not lose viability even after 120 hours.

C. MODES OF PERPETUATION OF THE DISEASE

The following experiments were conducted to study the modes of perpetuation of the disease :—

1. Planting of setts from smutted shoots of canes

Setts from smutted shoots of canes of variety Katha were planted after surface-sterilization in the field in April 1934 and the experiment was duplicated. Setts from healthy canes of the same variety were also planted after surface-sterilization in 0·1 per cent mercuric chloride solution for five minutes, to serve as control. Counts of smutted canes were taken regularly throughout the growing season and care was taken to avoid secondary infection from any outside source. Secondary infection from plant to plant in the same plot or from one plot to the other was avoided by uprooting the smutted stools on the same day the smut made its appearance, taking care that the spores were not shed at all. The results are presented in Table IV.

TABLE IV

Results of experiments on sowing setts taken from smutted shoots of canes

Year	Sown in	Treatment	No. of buds planted	No. of buds germinated	Percentage germination	No. of plants smutted	Percentage smut
1934	Field .	(*i*) Setts from smutted shoots of canes	200	32	16·0	32	100·0
		(*ii*) Setts from healthy canes	200	88	44·0	0	0
	Pots .	(*i*) Setts from smutted shoots of canes	100	18	18·0	18	100·0
		(*ii*) Setts from healthy canes	100	42	42·0	0	0
1935	Field .	(*i*) Setts from smutted shoots of canes	212	40	18·8	40	100·0
		(*ii*) Setts from healthy canes	222	97	43·6	0	0

It is clear from the figures given in Table IV that all the setts from the smutted shoots of canes which germinated produced smutted plants. All the shoots in such smutted plants were invariably smutted (Plate LX, fig. 1). The setts from healthy plants gave rise to healthy canes in all cases. It may also be recorded that smut began to appear in May and continued to appear till the end of July.

It should also be noted that germination in the case of setts from smutted shoots of canes was only 16·0 per cent against 44·0 per cent in the case of healthy canes. As disinfected setts from healthy canes when sown in the field away from other cane crops did not produce any smutted cane, in further experiments the use of pots was discontinued and all the plantings were done in field.

The experiment was repeated in 1935 with similar results which are also given in Table IV.

2. *Smearing of spores to the surface of buds of setts at the time of planting*

Disinfected buds of setts of variety Katha were smeared with fresh spores of smut and planted in the field. The experiment was conducted during 1935,

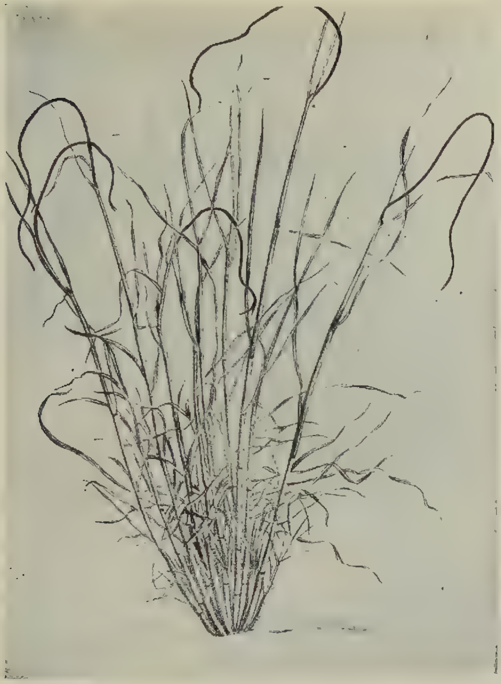


FIG. 1. A totally smutted stool

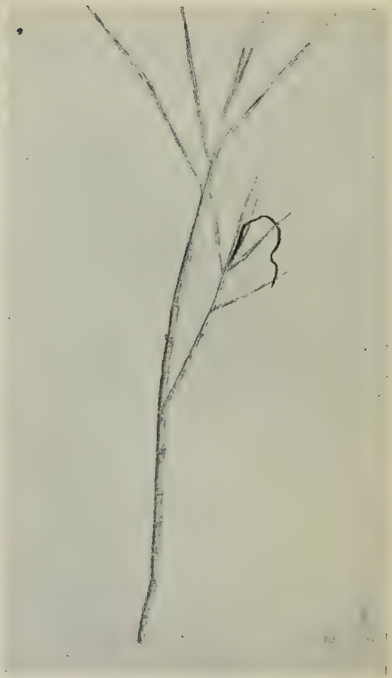


FIG. 2. Healthy cane showing a smutted side shoot

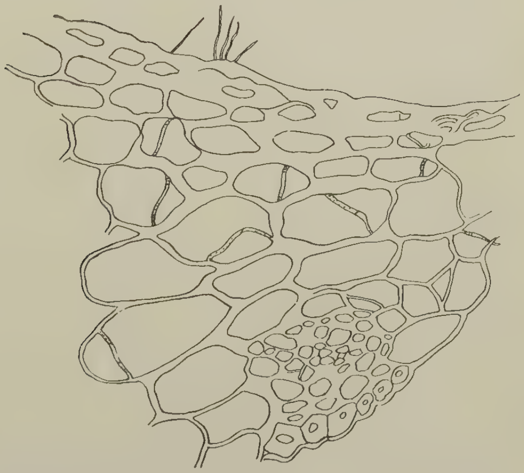


FIG. 3. A transverse section of a bud of cane infected with *Ustilago scitaminea*

3. Infection of the buds of standing canes

During the course of the investigation it was observed that even by avoiding planting setts from diseased canes and disinfecting the healthy canes before planting, one gets smutted canes in the crop. This suggested the possibility of the existence of some such method of infection by which the mycelium remains hidden inside some tissue of the cane. The infected cane looks apparently healthy and the infection shows itself only when on planting such canes smutted plants appear. Observations made during the growing season of the cane crop showed that the spores from smutted shoots are blown about by wind and fall on the neighbouring canes. It is well to point out here that many of the buds of standing canes are exposed and when the trash falls away the rind also becomes naked. Thus the spores reach the rind and the buds. These were found to germinate on the canes with the aid of the moisture provided by dew, etc., but the germ tubes produced by the spores were unable to pierce through the unwounded rind. These were found to enter the buds in many cases. After confirming by various trials that the germ tubes produced by the spores on germination were unable to pierce through the unwounded rind, systematic experiments were conducted to find out how far the buds of standing canes get infected and how far these are a source of carrying over the disease from year to year. These experiments are described below :—

During August 1935, buds of Katha canes standing in the field were smeared with spores and kept wet artificially. Sections cut later on showed numerous spores sending in their hyphae into the tissues of the buds (Plate LX, fig. 3). Such inoculated canes when left to grow gave smutted shoots from 60 out of 300 inoculated buds on the standing canes within three months. (A smutted shoot from such an inoculated bud is shown in Plate LX, fig. 2). The inoculated buds which did not sprout were sown in September, 1935, in the field after disinfection with 0·1 per cent mercuric chloride solution for five minutes. Setts from healthy canes the buds of which were not smeared with spores were also sown in the field after disinfection in 0·1 per cent mercuric chloride solution on the same date to serve as control.

The experiment was repeated in February and October 1936. The results are given in Table VI.

TABLE VI

Results of experiments on infection with smut spores on the buds of standing canes

Year	Treatment	Time of infection	Time of planting	No. of buds planted	No. of buds germinated	No. of smutted plants	Percentage smut
1935	(*i*) Buds of standing canes infected with spores and surface-sterilized	August .	September 1935	135	53	15	28·3
	(*ii*) Control . .	..	September 1935	160	65	0	0
	(*i*) Buds of standing canes infected with spores and surface-sterilized	August .	March 1936	330	113	30	26·5
	(*ii*) Do. . .	September.	March 1936	310	106	16	15·0
	(*iii*) Control . .	..	March 1936	710	249	0	0
1936	(*i*) Buds of standing canes infected with spores and surface-sterilized	February .	March 1936	1,500	600	26	4·3
	(*ii*) Control . .	..	March 1936	700	249	0	0
	(*i*) Buds of standing canes infected with spores and surface-sterilized	October .	October 1936	410	159	25	15·7
	(*ii*) Control . .	..	October 1936	100	38	0	0

From the results given in Table VI it is clear that the buds of standing canes infected with the spores of the fungus, when planted in the field, produced from 4·3 to 28·3 per cent smutted canes.

4. Ratooning of smutted canes

In order to see the effect of ratooning the smutted plants on the appearance of sugarcane smut, forty smutted canes were cut at the base in February 1935 and then the stumps were disinfected with 0·1 per cent mercuric chloride solution for fifteen minutes. Observations on the appearance of smut from the shoots arising from the ratooned canes were recorded. The results are given in Table VII. The experiment was repeated in 1936 with similar results

This finding confirms the results obtained by other workers that if the smutted canes are ratooned all the fresh canes arising from them are invariably smutted. That these smutted canes were given rise to by perennial mycelium in the stumps of ratooned canes and were not due to fresh infection of the cut ends by the spores, is clear from the fact that after the canes were cut at the bases the exposed surface was thoroughly disinfected.

TABLE VII

Results of experiments on ratooning of smutted canes

Year	Treatment	No. of canes ratooned	No. of plants smutted	Per cent smut
1935	(*i*) Ratooned from smutted canes .	40	40	100·0
	(*ii*) Ratooned from healthy canes .	40	0	0
1936	(*i*) Ratooned from smutted canes .	30	30	100·0
	(*ii*) Ratooned from healthy canes .	30	0	0

5. *Smearing of spores to the cut ends of setts at the time of planting*

Spores of smut were smeared to the cut ends of healthy disinfected setts of Katha variety, and the setts planted in the field as well as in sterilized pots. Healthy disinfected setts were also planted to serve as control. The experiment was conducted during 1935 and 1936 and in each year it was duplicated. Observations were made throughout the growing season. The result obtained was that in no case smut appeared, thus showing that under the conditions obtaining at Lyallpur, infection through cut ends of setts does not take place.

Thus from all the experiments described above it is concluded that the smut of sugarcane perpetuates by the following methods :—

1. By planting setts taken from smutted shoots of canes.
2. By spores which may adhere to the surface of buds of setts at the time of planting.
3. By aerial infection of buds of standing canes. In such cases the mycelium of the fungus remains dormant inside the buds.
4. By ratooning the smutted canes.

IV. Summary

1. Effect of different nutrient solutions, temperature and hydrogen-ion concentration on the germination of spores of *Ustilago scitaminea* Syd. has been studied.

2. Viability of spores under a variety of conditions has been tested.

3. Studies on the modes of perpetuation of the disease for four years have clearly shown that the disease is carried over from year to year by the following methods :—

1. By planting setts taken from smutted shoots of canes.
2. By spores adhering to the buds of setts at the time of planting.
3. By aerial infection of the buds of standing canes.
4. By ratooning smutted canes.

The writers' thanks are due to S. Harbans Singh, Sugarcane Specialist, Risalewala for placing at their disposal cane material and land for some field experiments.

The authors are jointly responsible for the work.

The investigation reported was carried out as part of the scheme of Sugarcane Research financed by the Imperial Council of Agricultural Research.

REFERENCES

Ajrekar, S. L. (1916). *Agric. J. Ind.* **11**, 292
Barat, H. (1931). *Bull. econ. Indochine, N. S.* **34**, 779B-796-B
Butler, E. J. (1906). *Mem. Dept. Agric. Ind.* (*Bot. Ser*) **1**, No. 3
————(1918). "Fungi and Disease in Plants," Calcutta. pp. 377-380
Clark, W. M. (1923). "The Determination of Hydrogen Ions." Baltimore
Da Camara, E. Des. (1930). *Ann. Inst. sup. Agron.* **3**, 59-141
Dastur, J. F. (1920). *Ann. Bot.* **34**, 391
Dodds, H. H. (1924). *Afric. Sug. and Cott. Plant.* **2**, 11-14
Freise, F. W. (1930). *Facts ab. Sug.* **25**, 613-614
Lee, H. A. (1922). *Philipp. Agric. Rev.* **14**, 422-434
Lee, H. A. and Medalla, M. G. (1922). *Philipp. Agric. Rev.* **14**, 402-412
Pritchett, G. H. (1924). *Louisiana Planter* **23**, 470-472
Shepherd, E. F. S. (1924). *Rev. Agric. Maurice* **14**, 107-108
Sydow, H. (1924). *Ann. Mycol. Berl.* **22**, 277-291
Sydow, H. and Butler E. J. (1906). *Ann. Mycol. Berl.* **4**, 424
Teng, S. C. (1932). *Contr. Biol. Lab. Sci. Soc. China. Bot. Ser.* **8**, 121-128

NEW ASILIDAE FROM INDIA, II (DIPTERA: ASILIDAE)

BY

STANLEY W. BROMLEY, Ph.D.

(Received for publication on 25th May 1938)

(With four text-figures)

A collection of Indian Asilidae sent me for study by Mr. M. C. Cherian, Entomologist to the Government of Madras, contain the following species which I am describing as new.

This is the second of a series of papers on the Asilidae of India, the first having been published in the *Records of the Indian Museum*, Vol. **37**, pp. 219-230, June 1935.

The types of the new species described in the following paper have been returned to Mr. Cherian. I am greatly indebted to Mr. Cherian for the opportunity of studying these specimens. Indian Asilidae are relatively little known and there is a wonderful opportunity for the taxonomist to contribute to the knowledge of this interesting group of flies through an intensive study of the Asilid fauna of this region.

I. Leptogastrinæ

Leptogaster cheriani sp. nov.

Total length, 13 mm. A reddish species : the legs yellowish, the posterior tibiae with the extreme apex brownish, mesonotum with three indistinct brown stripes, the scutellum brown in centre with yellowish margin, the wings hyaline, the veins yellowish brown, the anal cell open, the fourth posterior cell petiolate, and the anterior intercalary vein forming a distinct angle with that portion of the posterior cross-vein that closes behind the second posterior cell.

This is quite distinct from *L. marion* Walker, which has the antennae black, the legs yellow with the posterior femora and tips of posterior tibiae black, and the wings dark brown.

Male.—Proboscis reddish brown, palpi yellowish, mystax pale straw-coloured. Occipital bristles reddish. Face and vertex white pollinose. Occiput gray pollinose. Basal segment of antennae yellow, rest missing. Thorax reddish, the mesonotum with three indistinct brownish stripes. Pleura grayish white pollinose. Legs yellowish (front tarsi and tibiae missing), tip of posterior tibiae brownish. Wings hyaline, somewhat iridescent, veins yellowish brown. Halteres pale yellow, knobs pale brown. Centre of disk of scutellum brown, margin yellowish. Abdomen pale yellowish brown, first three tergites with dark brown spots above, dorsum and sides of abdomen with an indistinct whitish bloom. Genitalia reddish (fig. 1).

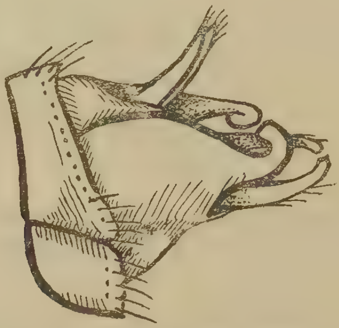


FIG. 1. *Leptogaster cheriani* sp. n. Male genetalia—lateral aspect

Holotype, male, South India, Coimbatore, January, 20, 1913. (P.S. Coll.) 75/35. I take pleasure in naming this unique species in honour of Mr. M. C. Cherian, Government Entomologist of Coimbatore, South India.

II. DASYPOGONINÆ

Scylaticus indicus sp. nov.

Total length, 11mm. A slender species with abdomen banded black and yellow, the feroma yellow, the tarsi and tips of tibiae (the posterior tibiae mostly) dark brown. The head is shown in Fig. 2.

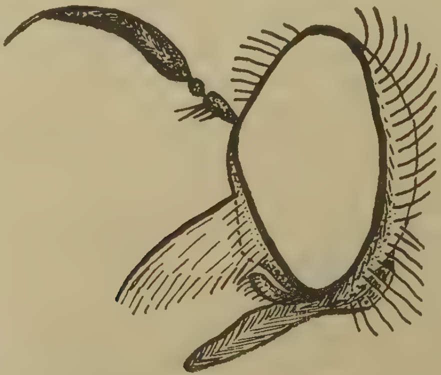


FIG. 2. *Scylaticus indicus* sp. n. Head—in profile

Male.—Antennae and proboscis dark brown. Vestiture of head pale yellow, pollinose areas yellow to yellowish gray, occiput decidedly grayish. Mesonotum grayish pollinose becoming more yellowish on the sides, pleura grayish yellow pollinose ; hairs and bristles of mesonotum pale yellow. Scutellum gray pollinose with six to eight yellow marginal bristles. Tuft of bristles in front of halteres sordid whitish. Halteres pale yellow. Wings hyaline. Legs yellowish with fine whitish hairs ; extreme apices of femora dark brown, posterior tibiae dark brown except extreme bases which are yellow. First two pairs of tibiae more or less brownish. Tarsi piceus. Abdomen yellowish, tergites one to six with broad black vittae making the abdomen appear banded with black, 7th tergite with a very small black dorsal spot. Genitalia yellowish with concolorous hairs.

Holotype, male, South India, Tinnevelly Hills, July 3-12, 1921. (At Mundantorai). (Ramakrishna Coll.) 67/35.

Stenopogon (*Scleropogon*) *raven* sp. nov.

Total length, 28 mm. A blackish brown species of the subgenus *Scleropogon* with smoky wings. The first posterior cell is closed and petiolate, the hypopleura (of Back) bare, the third segment of antenna longer than the first two together, the style bristle-like and about one third the length of the third segment. Differs from *S. subtus* Bromley, *S. ambyron* Walker and *S. damias* Walker in having the dorsum of the abdomen black, while *subtus ambryon* and *damias* have the abdomen more or less reddish. *S. piceus* Röder has the thorax yellow and the wings hyaline.

Male.—Head black (Fig. 3). Mystax largely straw yellow with an occasional brownish bristle. Palpi piceus with pale brown hairs. Beard and post-genal hairs straw coloured. Bristles of upper occiput, vertex and antennae black. Bristles of vertex proclinate, curving forward. Prothorax armed with numerous stout black bristles. Mesonotum blackish with grayish brown pollen. The humeri are reddish brown. Pleura grayish brown pollinose. Coxae gray pollinose with bushy straw coloured hairs and bristles, the anterior tip of the hind coxae with black bristles. Mesonotum with fine black and an abundance of stout black bristles posteriorly. Scutellum gray pollinose with numerous stout black marginal bristles. Wings smoky blackish, not opaque ; veins brownish. Halteres pale reddish brown. Legs piceus with black hairs and brisltes ; there are some fine pale hairs on the two anterior pairs of tibiae. Abdomen black, sides and dorsum grayish pollinose ; incisures brownish. Abdomen with short black hairs, the venter with long fine gray hairs. Apex of abdomen black, shining. Genitalia small, compact black.

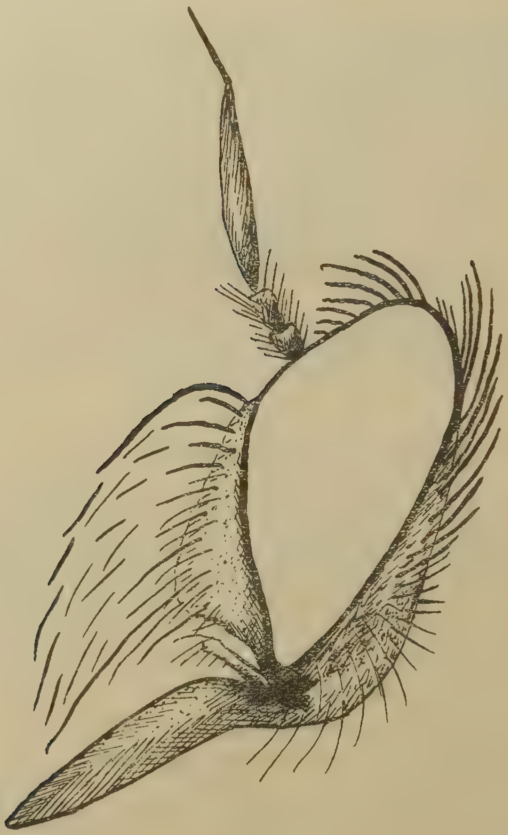


FIG. 3. *Stenopogon raven* sp. n. Head—in profile

Holotype, male, Kodaikanal, Pulney's May, 4-15, 1919. (Muliyil Coll.) 73/35.

III ASILINÆ

Philodicus propinquus sp. nov.

Total length, 24-27 mm. A black species, grayish pollinose, related to *P. pruthii* Bromley, but differs in having the pollen grayish white instead of grayish brown and the scutellum with four black marginal bristles instead of one pair.

Male.—Vestiture and pollen of head white, the mystax with a pale yellowish tinge. A few of the occipitals are black. Antennae black with black hairs. Thorax grayish white pollinose, the mesonotum with a double median line and two lateral spots on each side, black. Scutellum grayish white pollinose with white hairs and four marginal bristles, black. Legs dark reddish, the femora black, covered with white appressed hair which is very fine and short. Wings hyaline, the apices grayish. Abdomen black, with sides and posterior margins white pollinose. Hypopygium black, slightly shorter than segments six plus seven, with fine white pubescene along both sides.

Female.—Similar, ovipositor with 8th segment and following, shinning black.

Holotype, male, Chowghat, Ponani TQ, Sept. 28, 1920 (A.G.R. Coll.) 70/35. Allotype, female, Chowghat, Ponani TQ, Sept. 28, 1920 (A.G.R. Coll.) with prey, a tiger beetle. 70/35.

Promachus ramakrishnai sp. nov.

Total length, 25 mm. A black species, the abdomen banded with yellow, the femora black, the tibiae yellow with black tips. Differs from P. *ghumtiensis* Bromley in having the mystax entirely yellow and the hypopygium broader than the 7th segment, black with black hairs, but with a thick tuft of white hairs at the apex.

Male.—Mystax yellow; beard and post-genal hairs paler yellow. Palpi with yellow hairs mostly, but a few black hairs near base. Occipitals, hairs and bristles of vertex and antennae black. Mesonotum brown pollinose, the median line and lateral spots black. Pleura and borders of mesonotum gray pollinose. Scutellum grayish brown pollinose with pale hairs on disk and black bristles on margin. Wings brownish, a heavy black shadow in first submarginal cell. Coxae grayish white pollinose. Femora black, tibiae yellow with black tips, tarsi black. Abdomen yellowish pollinose, each tergite with a broad black vitta making the abdomen appear banded. Genitalia black, broader than 7th segment and slightly longer, black with black hairs, the tips with a thick tuft of white hairs (Fig. 4).

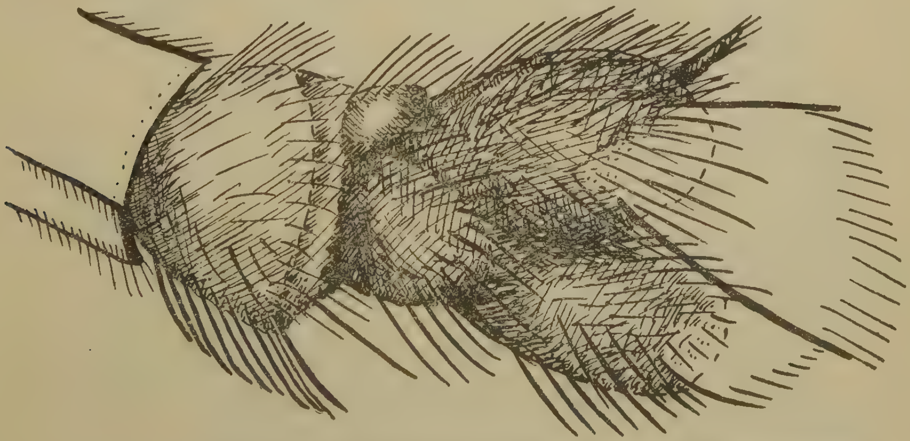


FIG. 4. *Promachus ramakrishnai* sp. n. Male genitalia—lateral aspect.

Holotype. male, N. Malabar, Taliparamba, Sept., 8-11, 1920. (Ramakrishna Coll.)

I am naming this fine species in honour of Dr. Ramakrishna Iyyer.

Note by M. C. Cherian, Entomologist to the Government of Madras

The types of the above newly-described species are deposited in the collections of the Agricultural Research Institute, Coimbatore (South India). The Coimbatore collections also contain the following species of Asilids :—(1) *Promachus maculatus* Fabr., (2) *P. heteropterous* Macquarl., (3) *P. duvaucelli* Macquarl., (4) *P. yerburiensis* Ricardo, (5) *Synoleus iamenus* Wlk. (6) *S. annulatus* Foh., (7) *Philodicus vandesseanus* Ricardo, (8) *P. insularis* Ricardo, (9) *Heligmoneura tricynata* Ricardo, (10) *Ommatius* (*Ommatinus*) *tenellus* Van der wulf., (11) *Ommatius chinensis* Fabr., and (12) *Allocotosia aurata* Fabr.

SELECTED ARTICLE

THE DEVELOPMENT OF SOIL MECHANICS

BY

F. L. D. WOOLTORTON, B. Sc., A. M. Inst. C. E.

(Reprinted from the *Structural Engineer*, Vol. 15, No. 8, August 1937, with permission of the Institution of Structural Engineers)

Though soil mechanics is not by any means a new science it is only of recent years that a serious attempt has been made to study the foundation soil by practical as well as by theoretical means. The recent progress has been truly phenomenal.

During a modern examination of a foundation soil the recognised procedure, followed in the United States and elsewhere, is aimed at tests which will enable a heavy structure, in the nature of a building to be constructed with a known ultimate sinkage and a light structure, in the nature of a road pavement, to be built subject to the least distortion. To achieve this end the simplified tests, based on those suggested by Atterberg, are used for comparing the properties of one soil with those of a similar soil whose properties are known—and these simplified tests are followed, when further or confirmatory information is required, by the tests given by Terzaghi.

Such tests supply information of great value but whether they give the investigator all the information he requires is not clear. Perhaps, because of the empirical nature of some of the tests, the investigator may sometimes feel a little doubtful on this point and should he be engaged on the examination of widely different soils he may feel that due consideration of this fact is not given by the usual tests.

In the early days of soil mechanics it was thought that information could be gathered from the results of mechanical and chemical analyses, but conflicting results persuaded the majority of investigators that their results were practically worthless. It is believed that this view is not so widely held as formerly and that there is a growing feeling that much can be learnt from the soil physicist and chemist whose knowledge of soil behaviour and properties is now of a more practical use to the engineer.

To take a specific example, it is instructive to consider the information which can be obtained from the shrinkage curve of volume-moisture content relationship for a definite soil type. The usual information obtained from this curve is the very important value of the shrinkage limit for the natural or remoulded specimen, the density of the soil particles and the apparent density of the soil under the conditions of testing. It also gives the total shrinkage under extremes of moisture content.

Supposing now it is necessary for the investigator to report on the conditions under which two buildings of identical design, on apparently the same soil, show different results in so far as one building cracks and the other does not. It is conceivable that the information given by a soil survey and the prescribed tests will not be sufficient for a satisfactory report and that the remaining information required might be supplied from the following consideration.

1. *The effect of yearly fluctuations of moisture content of the soil*.—This has a two-fold influence on the soil, part of which can be deduced from the shrinkage curve and part, a result of micro-relief, will be demonstrated by the soil chemist and pedologist in a change of soil type with a consequent change in mechanical properties such as might occur in the chernozem, solonschak, solonetz, solod cycle, all of which are conceivably found in the same area. It is sufficient here to consider the first influence.

MOISTURE CONTENT OF SOIL

The yearly variation in moisture content of a soil at foundation level can vary from something inappreciable to a figure of, say, 5 per cent, depending on the climatic conditions and the nature of the soil. The important consideration is in which zone of the shrinkage curve, for the undisturbed sample, this variation occurs. If the variation be in the lower region of the curve, that is in the area of residual shrinkage, then the shrinkage or swelling of the soil *in situ* due to yearly variation in moisture content will be less than if the variation occurred in the 45-degree range where the shrinkage will be more and the disruptive forces greater. In an example in mind the yearly variation corresponds to a volume change of 10 per cent a figure capable of inflicting very severe stresses on certain types of construction.

2. Following up this discussion of variation in moisture content two further points arise—*linear shrinkage* and *expansion pressure*, both of which have received little attention.

LINEAR SHRINKAGE

It is usually assumed that linear shrinkage can be taken as approximately one third of the volumetric shrinkage, but this ratio may be very far from the truth and appears to depend upon the soil type. The early results of research* now in progress indicate that for a sodium clay the horizontal and vertical shrinkages are not equal but that their ratio, instead of being unity, may be two to one for the undisturbed state—a condition visualised in G. R. Clarke's publication, "*A Study of the Soil in the Field,*" page 73[1], and Clarke is a soil chemist and not an engineer. The explanation for this irregularity, it is believed, lies in the nature of the soil structure, calcium clays tending towards a crumb structure and sodium clays, possibly, tending towards a laminated structure. This characteristic is possibly reflected in the geometry of the soil elements which may influence the shrinkage properties.

---

* By the author.

The samples of calcium clay examined indicate equal contractions in the vertical and horizontal directions but it is believed that with some calcium clays the ratio of horizontal to vertical shrinkage is in the reverse order to that for sodium clays, *i.e.*, the maximum shrinkage may occur in the vertical direction and, in consequence, the value of the swelling pressure (see below) may, in the case of calcium clay, be of far less importance than it is with a sodium clay, but this remains to be proved.

If such ratios of horizontal to vertical shrinkage were definitely established for the various soil types then therein might be found the explanation for such phenomenon as is illustrated by the sinusoidal curves of building deflection found in various parts of the world, for which, the writer believes, no explanation has as yet been given[2].

EXPANSION PRESSURE

Expansion pressure may, in certain parts of the world, be of great importance as it is conceivable that conditions are such that the foundations must be laid on an expansible soil. By expansion pressure is meant the pressure the soil is capable of exerting on certain types of foundations by virtue of its swelling due to the yearly variation in moisture content. A building carried by deep piles would comply with the requirements. If the axis of maximum expansion and contraction is the vertical axis then it is conceivable that the pressure on the foundations for buildings not constructed on piles, will be uniform and the building will not be affected, but should the maximum expansion occur in the horizontal direction then, on account of buckling of the soil, the effect is of a different nature and the swelling pressure becomes important.

The correct procedure for measuring this expansion pressure is not very clear, but experiments devised indicate, for sodium clay, a pressure of about three-quarters of a ton per square foot. The differential effects ascribed to the effect of abnormal horizontal shrinkage are illustrated in a paper by the writer published in Volume 3 of the *Proceedings of the International Congress of Soil Mechanics* held last June at Harvard, U.S.A. Since the submission of that paper further and more detailed information on the variation in soil levels has become available.

To return to the shrinkage curve, it suggests a line of investigation which may, when further information becomes available, be of great value to the soil engineer. In assessing the value of the following, due regard must be paid to the fact that it is based on research carried out in different parts of the world, that is on a few soil types only, and that these results, because they are few, are open to criticism. The discussion is given not as an established truth but as a suggested line of profitable investigation.

SHRINKAGE LIMIT

Whilst considering the range of soil moisture fluctuation in relation to the shrinkage limit, the question presents itself—what are the factors controlling the magnitude of the shrinkage limit, and are these factors of interest and help in an engineering study of the soil? Many physicists have tried to explain the significance of this value. Hardy[3],[4] working on Wildon's micro-reticulate structure of the clay-complex was able to analyse the moisture contained by clay at its condition of maximum plasticity, *i.e.*, approximately the upper limit for the determination of the volumetric shrinkage, and, according to his earlier investigations, on well defined geological soils of the tropics, came to the conclusion that the point at which shrinkage stopped represented the hygroscopic coefficient. Later on Hardy noted that this method could not for certain reasons be used for an accurate determination of the hygroscopic coefficient. In a more recent paper Hardy worked on the value of the moisture content at the upper limit of the residual shrinkage and found that these moisture contents were in excess of the hygroscopic coefficients[4]. From his reasons given for this discrepancy it appears that the true value of the hygroscopicity lies slightly below the upper limit or point of inflection.

It would therefore appear that the hygroscopic coefficient lies somewhere within the range of moisture content represented by the upper and lower limits of the residual shrinkage and it would seem that as a fair approximation the moisture content at the arbitrary shrinkage limit can be taken to represent the coefficient of hygroscopicity. It is of interest to note that this value is numerically equal to the volume of air in the oven dried test sample.

Results, therefore, indicate the possibility of a close relationship between the residual moisture and the hygroscopicity of any clay soil formed by any of the main geological processes.

This relationship is of more value than it appears as the discussion is capable of extension in a direction which should prove of service.

Hygroscopicity is a property of the soil, chiefly the colloidal fraction, by which it can absorb or adsorb moisture from the atmosphere, *i.e.*, the natural or soil atmosphere, in the form of films of molecular thickness. In other words it is a property of the clay complex, and any concentrated soil solution covering the clay complex. Only the part played by the soil complex will be considered as a discussion of that played by the soil solution leads directly into the realms of soil systematics.

As a corollary to E. W. Russell's paper, "*The Adsorption of Liquids by Clays*"[5], it appears that the adsorption of polar molecules, such as water, is mainly brought about by the exchangeable ions. What is important is that the relative values in decreasing order for different clays are Na-clay less than Ca-clay less than Mg-clay. The value for hydrogen clay usually lies between those for sodium and calcium.

This reduces the problem to a further study of the colloidal clay complex.

CLAY COMPLEXES

It has been left to the X-ray specialist to solve the controversy between the chemist and the mineralogist as to the nature of the various clay complexes—whether similar or widely different—whether crystalline or amorphous. A résumé of this work has been given by C. E. Marshall in " *The constitution of the Clay Minerals* "[6]. From his investigations of the clay fractions of soils it is shown that the known colloidal clay minerals are essentially crystalline and they are similar in so far as they can be conceived as composed of a lattice structure consisting of superposed layers of gibbsite and silica with a possible inclusion, in some cases, of brucite ; the difference between them lying in the number of hypothetical silica layers, the displacement of the silica layers relative to the gibbsite and the distance apart of the plains of cleavage which varies with the moisture content of the clay. A further deduction was that, in many cases, the clay subfraction consisted of a single clay mineral subject to base exchange though small in the case of kaolins.

From the above it appears that the residual moisture is a function of the hygroscopicity and that this is a function of the nature of the clay complex formed in any of the soils laid down by the main geological and weathering processes.

This latter deduction is not new. It was suggested by Vernadsky and, more recently, H. G. Byers in a paper " *The Chemical Composition of the Colloids of the Great Soil Groups* "[7], stated that in each group a representative soil series contains colloidal material characteristic of the series and also of the group to which the series belongs and he was able to give the predominant fundamental compounds to be found in the various groups.

Hardy,[3] working with tropical soils, practically humus free, further found that the ratio of the moisture at the point of maximum plasticity or sticky point to the hygroscopic coefficient was a constant for any of the definite geological soils examined by him.

Keen and Coutts[8] investigated the significance of the soil constants and although they were apparently unable to discover any relationship between the hygroscopicity and the residual moisture for the soils examined yet they did discover a close connection between the sticky point and the hygroscopicity at 50 per cent relative humidity and noted that this relationship was worthy of further attention. They found that the connection between the sticky point corrected for interstitial moisture was even more closely related to the hygroscopicity but no attempt appears to have been made to give the constants found for the various geological soils. If the existence of such constants can be demonstrated their values are of great importance.

In concluding this discussion it is suggested that the residual moisture is something which may, in the future, be of great guidance to the foundation engineer as it appears to be a direct indication of the nature of the soil complex.

As regards total swelling or shrinkage the coefficient again depends upon the soil type, the visible effects usually being greater for a sodium clay than for a calcium clay. The value depends upon the numerical difference between moisture content at the sticky point and that at the shrinkage limit. If the sticky point be taken as proportional to the hygroscopicity and this be considered as approximately equal to the shrinkage limit it follows that the shrinkage is proportional to the hygroscopicity or numerically proportional to the pore space, for a laboratory tested sample. Pore space then is an important factor.

The apparent density of Na-clay can be particularly high—a case is under investigation where this figure at one level of a profile reaches the high figure of 2·41 corresponding to a tested pore space of only 10 per cent, due, in this particular instance, to the specimen having been taken from the zone of accumulation where it may be assumed that the original larger pores have been filled with the colloidal clay brought up or down by weathering and soil-forming processes, and deposited there, in the main, irreversibly. A low value for this profile was 2·1 which is also high and an explanation for this is necessary.

The normal values for the pore space lie around the value of the minimum pore space of 26 per cent for an ideal soil composed of equal sized spheres. Tempany[9] envisualised much lower pore spaces in his theory of the ramification of the soil colloids throughout the mass of clay material and deduced from his results a lineal connection between the pore space and the linear shrinkage. He suggested that the limiting value of the linear shrinkage might correspond to that for pure colloidal clay, that is, he visualised a limiting case of a clay soil with no pore space.

Such a suggestion is consistent with the theory of the plate-like formation of some clays. With plates it is conceivable that a clay should have little or no pore space as opposed to a granular structure which must of necessity have an appreciable pore space and a low apparent density.

From the above discussion of one aspect of soil mechanics it is suggested that a case has been put forward for the active co-operation between the soil engineer, the chemist, physicist and mineralogist; that this collaboration is of vital importance for the full development of soil mechanics and that the time has arrived when each can be of definite service.

Some of the theories referred to are open to criticism on account of insufficient data and the localisation of the results. Some may even be discredited. But that is not the point, which is that valuable lines of investigation have been suggested by a non-engineering study of the soil and that some of these should be followed up in the interests of engineering.

The situation has been aptly described by a chemist in the following words —Soil science started as a science of the first few inches of soil to help the farmer. At the request of the forester it was extended to a depth of several feet and when extended to a depth of several yards will be of great help to the engineer.

BIBLIOGRAPHY

1. G. R. Clarke, " The Study of the Soil in the Field ", Clarendon Press, 1936, (now under revision)
2. F. L. D. Wooltorton, " A Preliminary Investigation into the Subject of Foundations in the ' Black Cotton ' and ' Kyatti ' Soils of the Mandalay District, Burma ". *Proceedings of the International Conference on Soil Mechanics and Foundation Engineering*, Vol. III, Harvard University, U.S.A.
3. F. Hardy, " The Physical Significance of the Shrinkage Coefficient of Clays and Soils. ", *Journal of Agricultural Science*, July 1923
4. F. Hardy, " Studies in Tropical Soils. III Shrinkage Behaviour of Lateritic Kaolinitic Soils ", *Journal of Agricultural Science*, 1934
5. E. W. Russell, " The Adsorption of Liquids by Clays ", *Trans. of the Third International Congress of Soil Science*, Oxford, 1935, Vol. **1**
6. C. E. Marshall, " The Constitution of the Clay Minerals ", *Science Progress* No. 119, 1936
7. H. G. Byers, " The Chemical Composition of the Colloids of the Great Soil Groups ", *Trans. of the Third International Congress of Soil Science*, Oxford, 1935, Vol. **1**
8. B. A. Keen and J. R. H. Coutts, " Single Value Soil Properties : A Study of the Significance of Certain Soil Constants ", *Journal of Agricultural Science*, 1928, Vol. **18**, page 740
9. H. A. Tempany, " The Shrinkage of Soils ", *Journal of Agricultural Science*, Vol. **8**, 1917

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

Annual Reports of the Executive Council of the Imperial Agricultural Bureaux.

List of Agricultural Research Workers in the British Empire, 1937*

OBTAINABLE FROM THE SECRETARY, EXECUTIVE COUNCIL, IMPERIAL AGRICULTURAL BUREAUX, 2 QUEEN ANNE'S GATE BUILDINGS, LONDON, S. W. 1, AND FROM H. M. STATIONERY OFFICE, LONDON, W. C. 2

The Journal of Dairy Research

Published by the Cambridge University Press on behalf of the Committee of Management. First issued in November, 1929.

	s.	*d.*
Volumes I to IV (each two parts)	25	0
Single parts	15	0
Volumes V to IX (each three parts)	25	0
Single parts	10	0

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Soils and Fertilisers

A comprehensive abstract journal of soil science published six times yearly.

	British Commonwealth		Foreign	
	s.	*d.*	*s.*	*d.*
Ordinary edition	20	0	25	0
Special edition (printed one side only)	25	0	30	0
Both editions	40	0	50	0
Single copies, ordinary edition only	5	0	5	0

Discontinued Series

The following series of multigraphed periodicals have now been incorporated in Soils and Fertilisers. Annual sets (some incomplete) are obtainable at the prices given below.

Publications relating to Soils and Fertilisers (monthly) 1935 (8 issues) 6*s*., 1936 (10 issues) 7*s*. 6*d*.; 1937 (10 issues) 7*s*. 6*d*.

Monthly Letters. 1935 (10 issues); 1936 (12 issues); 1937 (11 issues) 4*s*. per annum.

Recent Developments in Soil Analysis (quarterly), Complete Sets, 8*s*.

---

* 1938 Edition in preparation

Occasional Papers

Technical Communications—	*s.*	*d.*
37. Soil Structure, by E. J. Russell,	2	0
Annual Reports for the years 1929-30 to 1937-38 each	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions by the late Sir J. B. Harrison	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1934-37	25	0

II. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL HEALTH, VETERINARY RESEARCH LABORATORY, NEW HAW, WEYBRIDGE, SURREY

Abstracting Journal

The Veterinary Bulletin—	*s.*	*d.*
1931. Vol. I. Quarterly (1st Number, April)	7	6
Annual subscription	20	0
Subsequent Volumes. Monthly (1st Number, January)	5	0
Annual subscription (postage paid) (Back numbers still available)	40	0
Indexing Publication		
Index Veterinarius. First issue April, 1933. Annual subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed	100	0
(Vols. I—V issued quarterly. Vol. VI onward issued half yearly) (Back numbers still available).		
Occasional papers		
Review series—		
No. 1. Bovine Mastitis by E. M. Peterson	10	0

III. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL NUTRITION, ROWETT RESEARCH INSTITUTE, BUCKSBURN, ABERDEEN

Journal

Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)	*s.*	*d.*
Subscription per Volume of 4 numbers	42	0
Per single number	13	0
Occasional Papers		
Technical Communications—		
10. Table of Composition of Foods giving Energy Value, Protein, Fat, Carbohydrate, Calcium, Phosphorus and Iron Content of Some 300 Foods Commonly used in Great Britain and Compiled for Use in the Analysis of Dietary Surveys	1	0
Occasional Communications—		
2. Etiology of Endemic Goitre		

IV. OBTAINABLE FROM THE IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS, PLANT BREEDING INSTITUTE, SCHOOL OF AGRICULTURE, CAMBRIDGE

Journal

Plant Breeding Abstracts—

	s	d.
Quarterly. Annual Subscription	*25	0
Single copy	7	6
Volume I (Nos. 1, 2 and 3 out of print) No. 4 available	7	6
,, II Out of print	..	
,, III (Nos. 1, 2 and 4 out of print) No. 3 available	7	6
,, IV (Nos. 1, 2 and 4 out of print) No. 3 available	7	6
,, V (No. 2 out of print), Nos. 1, 3, 4 available	17	6
,, VI (complete)	20	0
,, VII (complete)	20	0
Numbers printed on one side of paper	30	0

Occasional Papers

Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
Subject Index to Vols. VI and VII of Plant Breeding Abstracts	2	6
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932-35. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication with the Imperial Bureau of Pastures and Forage Crops)	10	0
Bibliographical Monographs—		
Tobacco Breeding Bibliography	1	0

V. OBTAINABLE FROM THE IMPERIAL BUREAU OF PASTURES AND FORAGE CROPS, WELSH PLANT BREEDING STATION. AGRICULTURAL BUILDINGS, ALEXANDRA ROAD, ABERYSTWYTH, WALES

Journal

Herbage Abstracts—

	s.	d.
Vol. 7, 1937 (printed both sides)	15	0
Vol. 7, 1937 (printed one side only)	20	0
Vol. 8, 1938 (published price)	25	0
Vol. 8, 1938 (Price in Great Britain and British Commonwealth)	20	0
Herbage Reviews—		
Vol. 5, 1937	10	0
Vol. 6, 1938	†15	0

---

* 20s. to subscribers in the British Commonwealth

† A reduction of 5s. will be given when Herbage Abstracts is also ordered

Occasional Papers

Bulletin—

	s.	*d.*
Erosion and Soil Conservation*	5	0

VI. Obtainable from the Imperial Bureau of Horticulture and Plantation Crops, East Malling Research Station, East Malling, Kent

Journal

	s.	*d.*
Horticultural Abstracts. A quarterly abstract publication of current horticultural literature		
Vol. I. First issued, March, 1931. No. 2. Single copy	1	6
Vol. II Nos. 1, 2 and 3 out of print. No. 4, single copy.	1	6
Vols. III to VII, each (single copy 4 *s.*)	15	0
Vols. VIII and subsequent volumes. Annual subscription	†25	0
Single copy	6	6

Technical Communications

	s.	*d.*
10. Plant Injection for Diagnostic and Curative Purposes. 1938. W. A. Roach	5	0

Occasional Papers

	s.	*d.*
5. Frameworking of Fruit Trees. R. J. Garner and W. F. Walker	1	0

Proceedings of First Imperial Horticultural Conference, 1930—

	s.	*d.*
Part II. Papers on the application of Science to Horticulture. 1931. 2*s*. Out of print, but the following separates are available, each	0	3

Field Experiments in Certain Tropical and Sub-Tropical Crops in West Africa (Dr. E. J. Martin and W. H. Beckett).

Fruit Products and Associated Problems (Professor B. T. P. Barker).

Some Physiological Considerations in Horticulture (Professor V. H. Blackman).

Plant Physiological Work in the Tropics: Some of the Problems, with Special Reference to Cocoa and some Possible Lines of Attack (Dr. T. G. Mason and Dr. E. J. Maskell).

Soil and Survey Work as a Basis for Fruit Production in Irrigated Areas (Professor A. J. Prescott).

	s.	*d.*
Part III. Papers on Progress in Fruit Storage Methods, 1931, 2*s*. 6*d*. Out of print, but the following separates are available, each	0	3

Factors Influencing the Storage Qualities of Fruit (Dr. T. Wallace).

The Present Position of the Bitter-Pit Problem in Australia (W. M. Carne, H. A. Pittman and H. G. Elliott).

The Behaviour and Diseases of the Banana in Storage and Transport (Dr. C. W. Wardlaw and Dr. L. P. McGuire).

Problems of Storage and Transport (E. A. Griffiths)

Fruit Transport Problems in Canada (R. L. Wheeler)

---

* Joint publication of bureaux of Soil Science and Pastures and Forage Crops

† 20*s*. a volume or 5*s*. a number to subscribers in the British Commonwealth.

The Infection and Invasion of the Apple Fruit by Fungi in Relation to the Problem of Storage (Dr. A. S. Horne)

Experiments on the Preservation of Citrus Fruits (Dr. W. J. Young and F. M. Read).

Other Publications—

Index to Volumes I—X of the *Journal of Pomology and Horticultural Science* 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science*

	s.	*d.*
Available from the Bureau	5	0
Old and new standpoints on senile degeneration, 1931. By. A. P. C. Bijhouwer	0	6

VII. OBTAINABLE FROM THE IMPERIAL BUREAU OF ANIMAL BREEDING AND GENETICS, INSTITUTE OF ANIMAL GENETICS, UNIVERSITY OF EDINBURGH, KINGS' BUILDINGS, WEST MAINS ROAD, EDINBURGH

Journal

	s.	*d.*
Animal Breeding Abstract (quarterly) from Vol. 6 (1938)—		
Annual subscription	25	0
Subscribers in the British Commonwealth	20	0
Earlier Vols. from 1933, Vols. I-V. Annual subscription	15	0

Occasional Papers

Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0
Also obtainable from the Bureau:		
The Genetics of the Horse, 1930. Reprinted from 'Bibliographia Genetica'	0	6
Inheritance of Productivity in Farm Stock, 1935. Reprinted from 'Empire Journal of Experimental Agriculture'	0	6
The Genetics of the Pig, 1936. Reprinted from 'Bibliographia Genetica'	2	6

VIII. OBTAINABLE FROM THE IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY (HELMINTHOLOGY), INSTITUTE OF AGRICULTURAL PARASITOLOGY, WINCHES FARM DRIVE, HATFIELD ROAD, ST. ALBANS, HERTS

Journal

Bibliography of Helminthology. For the years 1930, 1931, 1932, 1933— Library Edition, bound in cloth per volume	10	6
Stiff paper cover only, per volume	8	0
Helminthological Abstracts (1932 onwards). Issued in five or six parts per volume, each volume covering the literature published in a single year. Subscription per volume (payable in advance)	30	0
Complete volumes bound in cloth	32	0

[NOTE:—From vol. III (1934) this journal incorporates the *Bibliography of Helminthology* and is published by the Bureau instead of by the *Journal of Helminthology*.]

Other Publications

(*j*) Helminth parasites of New Zealand By May R. Young 19 pp.	4	0
Notes and Memoranda—		
11. Recent Developments in the Control of Heterodera marioni, 6 pp.	1	0

PUBLICATIONS ISSUED BY THE IMPERIAL INSTITUTE OF ENTOMOLOGY, 41, QUEEN'S GATE, LONDON, S. W. 7

Bulletin of Entomological Research—

	s.	*d.*
Published quarterly, and containing original articles on Economic Entomology. Issued post free		
Annual Subscription (payable in advance)	30	0
Subscription to current volume received after 30th June	36	0
Separate parts	9	0
Back Volumes.—I (1910)—X(1919)	20	0
XI (1920)—XXIII(1932)	25	0
XXIV (1933) *et seq.*	37	6
Bound Volumes (extra to above prices)	6	0
Binding cases only	3	6

Reprints of some of the papers published in this Journal are available. Prices on application.

Review of Applied Entomology—

Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series.—

Series 'A' dealing with insect and other Arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin.

Series 'B' dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post free.

	Series 'A'		Series 'B'	
	s.	*d.*	*s.*	*d.*
Annual Subscription (payable in advance)	30	0	15	0
Subscription to current volume received after 30th June	36	0	18	0
Separate parts	3	0	1	6
Annual Subject Index (when sold separately)	6	0	3	0
Subject Index—Vols. I—III	5	0	I-X 10	0
Back Volumes—Vol. I (1913)-VII, per volume	15	0	10	0
Vol. VIII (1920)-XXII (1934) per volume	24	0	12	0
Vol. XXIII (1935) *et seq.* per volume	42	0	21	0
Bound Volumes (extra to above prices)	5	0	5	0
Binding cases only	3	6	3	6

The index to the current volume is not published until April (Series 'B') or August (Series 'A') of the following year.

Zoological Record—Part Insecta—

Published annually about July in each year and containing as complete a record as possible of the literature of the previous year, chiefly from the systematic standpoint.

	s.	*d.*
Annual Subscription (including postage)	15	6
Back Volumes.—Vols. LII (1915)-LVII (1920)	12	0
Vols. LVIII (1921) *et seq.*	15	0

Postage extra.

Some of the Sections into which Volumes LXI-LXVII were divided are still available. Prices on application.

The Biological Control of an Insect in Fiji—

By T. H. C. Taylor, M. Sc. (Lond.). An account of the Coconut Leaf-mining Beetle and its Parasite Complex. Royal 8 vo. pp. X and 239 with 23 plates, 2 maps and 17 text figures. Bound in cloth. Price 12*s*. Postage, inland, 6*d*.; abroad, 10*d*. 1937.

Report of the Fourth Imperial Entomological Conference, 19th-27th September, 1935.

Royal 8 vo. 70 Pp. Paper covers. Price, 4*s*. 0*d*. 1935.

Orders may be sent direct to the Assistant Director, Imperial Institute of Entomology, 41, Queen's Gate, London, S. W. 7, or through a bookseller.

Publications Obtainable from the Imperial Mycological Institute Kew, Surrey

Journal

Review of Applied Mycology—

	s.	*d.*
Annual Subscription, 12 monthly parts, with title-page and index (post free)	*30	0
Single part	3	0
Title-page and index	4	0

Back volumes (with the exception of Vols. I, VII and VIII, which are out of print) can be supplied, postage extra.

Occasional Publications

Annotated Account of Fungi Received at the Imperial Mycological Institute

	s.	*d.*
List I	1	0
List II, Fasc. 1	1	0
List II, Fasc. 2	2	0
List II, Fasc. 3. General Part	1	0
Report on the Third Imperial Mycological Conference, 1934	2	0
Mycologists resident in the British Empire, 1938	1	0

---

*24*s*. to subscribers in the British Commonwealth, who send their subscription direct to the Institute.

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian Postage]

1. Agriculture and Live-stock in India

ICAR. 1.	A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the Tropics. (Established 1931. Published in January, March, May, July, September and November. Prepayable subscription Rs. 6 or 9*s.* 9*d.* per annum. Price per part Rs. 2 or 3*s.* 6*d.*). Volumes I to VIII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5.	A bi-monthly scientific journal of agriculture and the allied sciences, mainly devoted to the publication of the results of original research and field experiments. (Established 1931. Published in February, April, June, August, October and December. Prepayable subscription Rs. 15 or 24*s.* per annum. Price per part Rs. 3 or 5*s.* 3*d.*). Volumes I to VIII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6.	A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931. Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s.* 9*d.* Price per part Rs. 2 or 3*s.* 6*d.*). Volumes I to VIII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10·1	No. 1. The Fungi of India. By E. J. Butler, C.I.E., D.Sc., M.B., F.R.S. and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s.*
ICAR. 10·2	No. 2. Life-histories of Indian Microlepidoptera, Second Series: Alucitidæ (Pterophoridæ, Tortricina and Gelechiadæ). By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s.* 6*d.*
ICAR. 10·3	No. 3. The Open Pan System of White-Sugar Manufacture. By R. C. Srivastava, B.Sc. (1935, 2nd Edition.) Price Rs. 3-2-0 or 5*s.* 6*d.*
ICAR. 10·4	No. 4. Life-histories of Indian Microlepidoptera; Cosmopterygidæ to Neopseustidæ. By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. 1933). Price Rs. 4-8-0 or 7*s.* 6*d.*
ICAR. 10·5	No. 5. The Bombay Grasses. By E. J. Blatter, S.J., Ph.D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. (1935). Price Rs. 20 12-0 or 32*s.* 6*d.*
ICAR. 10·6	No. 6. Helminth Parasites of the Domesticated Animals in India. By G. D. Bhalerao, M.Sc. (1935). Price Rs. 7-12-0 or 13*s.* 3*d.*

ICAR. 10·7	No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng., and the Isolation of Types Resistant to the Disease. By W. McRae, M.A., D.Sc. (Edin.), F.L.S. and F. J. F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s.* 3*d.*
ICAR. 10·8	No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy. By C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s.* 9*d.*
ICAR. 10·9	No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah-Shell Oil Storage and Distributing Company of India, Ltd. By C. P. G. Wade. (1935). Price Rs. 3-14-0 or 6*s.* 6*d.*
ICAR. 10·10	No. 10. The Spotted Boll-Worms of Cotton (*Earias fabia* Stoll and *Earias insulana* Boisd.) in South Gujarat, Bombay Presidency. (Final report on investigations financed by the Indian Central Cotton Committee, 1923-1931). By B. P. Deshpande, M.Ag. and N. T. Nadkarny, B.Ag. (1936). Price Rs. 5-14-0 or 9*s.* 6*d.*
ICAR. 10·11	No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus muscles and the formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations. By. H. N. Chelva Ayyangar, G.M.V.C. (1937). Price Rs. 4-10-0 or 7*s.* 9*d.*
ICAR. 10·12	No. 12. The Fungi of India, Supplement I. By B. B. Mundkur. Price Rs. 1-6-0 or 2*s.* 3*d.*

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8·1	No. 1. List of Publications on Indian Entomology, 1930. Compiled by the Imperial Entomologist, Pusa. (1934). Price As. 14 or 1*s.* 6*d.*
ICAR. 8·2	No. 2. List of Publications on Indian Entomology, 1931. Compiled by the Imperial Entomologist, Pusa. (1934). Price As. 8 or 10*d.*
ICAR. 8·3	No. 3. List of Publications on Indian Entomology, 1932. Compiled by the Imperial Entomologist, Pusa. (1934). Price As. 12 or 1*s.* 3*d.*
ICAR. 8·4	No. 4. Host Plant Index of Indo-Ceylonese Coccidae. By S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. (1934). Price Rs. 1-10-0 or 2*s.* 9*d.*
ICAR. 8·5	No. 5. List of Publications on Indian Entomology, 1933. Compiled by the Officiating Imperial Entomologist, Pusa. (1935). Price As. 9 or 1*s.*
ICAR. 8·6	No. 6. Bee-keeping. By C. C. Ghosh, B.A., F.R.E.S. (3rd Edition.) (1936). Price Rs. 1-14-0 or 3*s.* 3*d.*
ICAR. 8·7	No. 7. List of Publications on Indian Entomology, 1934. Compiled by the Imperial Entomologist, Pusa. (1935). Price Rs. 1-2-0 or 2*s.*
ICAR. 8·8	No. 8. Selected Clinical Articles, Part I. By G. K. Sharma, G.P.V.C. and R. L. Kaura, B.V.Sc., M.R.C.V.S. (1936). Price As. 8 or 10*d.*
ICAR. 8·9	No. 9. Statistical Methods and their Application to Agronomy; A bibliography. Compiled by K. K. Guha Roy, B.A. (1936). Price Rs. 2-2-0 or 4*s.*
ICAR. 8·10	No. 10. Diseases of Sugarcane and Methods for their Control. By L. S. Subramaniam. (1936). Price Rs. 1-14-0 or 3*s.* 3*d.*
ICAR. 8·11	No. 11. Tables of Standard Errors of Mendelian Ratios. Compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell) and P. Krishna Rao, L.Ag. (1936). Price As. 12 or 1*s.* 3*d.*

ICAR 8·12	No. 12. List of Publications on the Botany of Indian Crops, Part II, for the period 1928-32, Compiled by R. D. Bose, B.Sc. (1936). Price Rs. 3-6-0 or 5*s*. 9*d*.
ICAR. 8·13	No. 13. Two New Statistical Tables based upon Fisher's '*t*'. By M. Vaidyanathan, M.A. (1936). Price As. 6 or 8*d*.
ICAR. 8·14	No. 14. List of Publications on Indian Entomology (1935). Compiled by the Imperial Entomologist, Pusa. (1936). Price Rs. 1-4-0 or 2*s*.
ICAR. 8·15	No. 15. Selected Clinical Articles, Part II. By G. K. Sharma, G.P.V.C., R. L. Kaura, B.V.Sc., M.R.C.V.S., S. Ganapathy Iyer, G.M.V.C., G. S. Khan, B.Sc., and M. Y. Mangrulkar, M.Sc., M.R.C.V.S., D.T.V.M. (Edin.) (1937). Price Rs. 1-4-0 or 2*s*.
ICAR. 8·16	No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders. By P. E. Lander, M.A., D.Sc., F.I.C., I.A.S. (1937). Price Rs. 3-14 or 6*s*. 9*d*.
ICAR. 8·17	No. 17. A Brief Survey of some of the Important Breeds of Cattle in India. By Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S., F.N.I. (1938). Price Rs. 2 or 3*s*. 6*d*.
ICAR. 8·18	No. 18. Milk Records of Cattle in Approved Dairy Farms in India. By K. P. R. Kartha, B.A. Price Rs. 2-12-0 or 4*s*. 6*d*.
ICAR. 8·19	No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province. By Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.), F.N.I. and H. N. Batra, B.Sc., Assoc. I. A. R.I. Price Re. 1 or 1*s*. 9*d*.
ICAR. 8·20	No. 20. Report on an Enquiry into the Cultivation of Cloves in India. By A. K. Yegna Narayana Iyer, M.A., Dip. Agri. (Cantab.). Price Rs. 2-4-0 or 3*s*. 9*d*.
ICAR. 8·21	No. 21. Investigations on the Cold Storage of Mangoes. By G. S. Cheema, D.Sc., I.A.S., D. V. Karmarkar, M.Sc., Ph.D., A.I.I.Sc. and B. M. Joshi, M.Sc. (*In the Press.*)

6. Annual Report of the Imperial Council of Agricultural Research

ICAR. 12·31	Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.
ICAR. 12·32	Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.
ICAR. 12·33	Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of stock.)
ICAR. 12·34	Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Rs. 1-8-0 or 2*s*. 6*d*.
ICAR. 12·35	Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.
ICAR. 12·36	Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.
ICAR. 12·37	Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Rs. 1-2-0 or 2*s*.
ICAR. 12·38	Annual Report of the Imperial Council of Agricultural Research for the year 1937-38. Price As. 12 or 1*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9·29	Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock.)

ICAR. 9·31	Review of Agricultural Operations in India, 1929-31. Price Rs 5 or 8*s*. 3*d*.
ICAR. 9·33	Review of Agricultural Operations in India, 1931-33. Price Rs. 5-12-0 or 9*s*. 6*d*.
	Agriculture and Animal Husbandry in India, 1933-34 and 1934-35—
ICAR. 13·1·35	Part I.—Crop Production. Price Rs. 4-14-0 or 8*s*.
ICAR. 13·2·35	Part II.—Animal Husbandry. Price Re. 1 or 1*s*. 9*d*.
ICAR. 13·36	Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10 or 7*s*. 9*d*.

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2	Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to the 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s*. 6*d*.
ICAR. 22	Proceedings of the Second Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at Madras from the 14th to the 16th December 1936, with Appendices. Price Rs. 3-10-0 or 6*s*. 3*d*.
ICAR. 3	Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s*. 9*d*.

9. Catalogue of Indian Insects

The following parts have been issued :—

ICAR. 11·1	Acrydidæ (Tettigidæ). By T. Bainbrigge Fletcher. 1921. Price As. 11.
ICAR. 11·2	Culicidæ. By R. Senior-White. 1923. Price Rs. 1-10.
ICAR. 11·3	Bombyliidæ. By R. Senior-White. 1923. Price As. 8.
ICAR. 11·4	Trypetidæ (Trypaneidæ). By R. Senior-White. 1924. Price As. 8.
ICAR. 11·5	Nitidulidæ. By S. N. Chatterjee. 1924. Price As. 10.
ICAR. 11·6	Staphylinidæ. By M. Cameron. 1925. Price Rs. 1-14.
ICAR. 11·7	Lasiocampidæ. By T. Bainbrigge Fletcher. 1925. Price As. 12.
ICAR. 11·8	Amatidæ (Syntomidæ). By T. Bainbrigge Fletcher. 1925. Price As. 12.
ICAR. 11·9	Zygænidæ. By T. Bainbrigge Fletcher. 1925. Price Rs. 1-5.
ICAR. 11·10	Stephanidæ. By G. R. Dutt. 1925. Price Rs. 1-2.
ICAR. 11·11	Brenthidæ. By Richard Kleine. 1926. Price Rs. 1-2.
ICAR. 11·12	Tabanidæ. By R. Senior-White. 1927. Price Rs. 1-12.
ICAR. 11·13	Cicindelidæ. By Mercia Heynes-Wood and Cedric Dover. 1928. Price Rs. 2-8.
ICAR. 11-14	Palpicornia. By A. d'Orchymont. 1928. Price Rs. 2-8.
ICAR. 11-15	Cecidomyidæ. By R. Senior-White. 1928. Price As. 7.
ICAR. 11-16	Cosmopterygidæ. By T. Bainbrigge Fletcher. 1928. Price As. 10.
ICAR. 11·17	Yponomeutidæ. By T. Bainbrigge Fletcher. 1928. Price As. 8.
ICAR. 11·18	Carabidæ. By H. E. Andrewes. 1931. Price Rs. 8-10.
ICAR. 11·19	Gyrinoidea. By Georg Ochs. 1930. Price As. 12.
ICAR. 11·20	Alucitidæ (Pterophoridæ). By T. Bainbrigge Fletcher. 1931. Price Rs. 1-6.
ICAR. 11·21	Lycidæ. By R. Kleine. 1931. Price Rs. 1-2.
ICAR. 11·22	Phaloniadæ and Chlidanotidæ. By T. Bainbrigge Fletcher. 1931. Price As. 6.
ICAR. 11·23	Chalcidoidea. By M. S. Mani, M.A. (Res.), 1937. Price Rs. 3-2 or 5*s*. 6*d*.

10. Miscellaneous Publications

VRI. 1	A Description of the Imperial Institute of Veterinary Research, Muktesar, and its Sub-station, the Imperial Veterinary Serum Institute, Izatnagar. By F. Ware, F.R.C.V.S., I.V.S. Price Rs. 1-4-0 or 2*s*.
ARI. 7. 187	The Production of Cigarette Tobacco by Flue-curing. By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. and Kashi Ram. *Imp. Inst. Agri. Res., Pusa Bull.* No. 187. Reprinted (1935). Price Re. 1 or 1*s*. 9*d*.
ICAR. 16	A Handbook of Statistics for use in Plant Breeding and Agricultural Problems. By F. J. F. Shaw, C.I.E., D.Sc., A R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s*. 3*d*.
ICAR. 7	Report on the Work of the Imperial Council of Agricultural Research in Applying Science to Crop Production in India. By Sir John Russell, D.Sc., F.R.S. Price Rs. 1-14 or 3*s*. 3*d*.
ICAR. 18	Report on the Development of the Cattle and Dairy Industries of India. By Norman C. Wright, M.A., D.Sc., Ph.D. Price Rs. 1-8-0 or 2*s*. 6*d*.

Copies of the above publications can be had from the Manager of Publications, Civil Lines, Delhi and from any of the Agents, a list of whom will be found on the inside page of the front cover. Prices are inclusive of packing and Indian postage.

Purchasers not residing in Asia, should apply to the High Commissioner for India, India House, Aldwych, London.

Note.—When indenting please give only the symbol preceding the name of the publication

Correction

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE, VOL. 8, PART I, FEBRUARY 1938

Pages 33 and 34, the footnotes—

" †Degrees of freedom for correlation coefficients are one less than those given in this column " should be deleted. The mark † should also be deleted from the body of Tables VIII and IX.

GIPD—S3—350 IC of AR—10-12-38—800.